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# Creativity, Psychology and the History of Science

Edited by
Howard E. Gruber and Katja Bödeker

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# CREATIVITY, PSYCHOLOGY AND THE HISTORY OF SCIENCE

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# PREFACE

Jürgen Renn

Psychologists have often exploited the history of science as a reservoir of examples for studies of creativity. In the same vein, historians of science occasionally refer to psychological research in order to enrich narrative accounts with insights into the working of the human mind. Howard Gruber's contributions to the understanding of creativity are path-breaking because they distinguish themselves from these one-sided approaches. They stand out with their profound understanding of both the historical and the psychological dimensions of scientific creativity. Gruber's insights are based on a combination of detailed case studies and the development of a theoretical framework that is closely integrated with his historical investigations. His work is part of the larger enterprise of conceiving human thinking as an evolving system driven by the reflection of interactions of the subject with the real world, an enterprise launched by Jean Piaget with whom Gruber collaborated intensively.

This book offers a comprehensive survey of Gruber's work and focuses on the heritage he left behind for building a historical theory of the development of human knowledge in which individual creativity can be understood within its changing historical contexts. It covers a broad array of his work and opens with two introductions, one by Katja Bödeker, which places this work within the framework of different theoretical approaches bearing on the relation between psychology and the history of science. The second introduction is written by Howard Gruber himself and offers a masterfully succinct account of his evolving systems approach.

The idea for this book emerged during a memorable visit of Howard Gruber and his wife Doris Wallace to the Max-Planck-Institute for the History of Science in the summer of 1999.

The plan to assemble Gruber's widely dispersed publications into this collection and hence reveal the hidden bonds that make evident the coherence of his life work was first conceived by my friend and colleague Peter Damerow, who also suggested the name of Katja Bödeker as a collaborator on this project.

Katja Bödeker, a student of Wolfgang Edelstein, director emeritus of the Max Planck Institute for Human Development, is a psychologist and historian of science working in the interdisciplinary tradition founded by Howard Gruber. In her dissertation she has analyzed intuitive physical knowledge developed in widely differing cultural backgrounds. She has thus significantly contributed to our understanding of the interplay between universal and culture-specific dimensions in the knowledge underlying scientific thinking. Her familiarity with both the wide range of theoretical approaches in cognitive psychology and the questions of historical epistemology, as pursued at the Max Planck Institute for the History of Science, made her an ideal cooperation partner for Howard Gruber. During an extended visit with Howard Gruber and Doris Wallace in New York, this cooperation grew into a friendship. Last but not least, it is also Doris Wallace's unfailing engagement and encouragement that enabled this ambitious project to be brought to a successful conclusion.

In the last months before its completion, this joint endeavor was overshadowed by Howard Gruber's grave illness. To our great chagrin, his unexpected death unfortunately prevented him from seeing the book published. All of us who have known him will forever miss his wisdom and wit, his friendliness and human warmth. May this volume serve as a reminder of what one can achieve in a life with a purpose.

# INTRODUCTION

*Growth of knowledge* is not the subject of a single dedicated discipline. Even within psychology, the acquisition, development and transmission of knowledge are addressed by sub-disciplines such as developmental psychology, expertise research, cognitive psychology, or creativity research, each pursuing the topic in a theoretically and methodologically distinct way. Outside the realm of psychology, historians of science analyze historical forms of knowledge and how they change, whereas anthropologists focus on the interaction between knowledge and its cultural and linguistic contexts—just to give two examples. This disciplinary variety testifies that growth of knowledge transcends the confines of a single discipline.

Though academic division of labour is generally appreciated as one of the most innovative ways of conducting science, the disciplinary splitting up of a topic often rests on presuppositions which may lead a research enterprise into false directions. So, for instance, the psychological perspective on the growth of knowledge is often ahistorical. The evolution of cognitive constructs, such as number, the species concept, or the idea of the self, is taken to proceed according to developmental stages or laws which hold universally, irrespective of historical or cultural determinants. Furthermore, historical underpinnings of the topic itself—such as the changing use of knowledge, its storage or distribution—are mostly disregarded. How, therefore, can research on the growth of knowledge be conducted which doesn't run into disciplinary reductionism? The answer seems to be straightforward: Research on the growth of knowledge should be interdisciplinary!

Yet the magic word "interdisciplinarity" exposes rather than solves the problem. What would interdisciplinary research on the growth of knowledge look like? Would it mean large conferences with participants from various disciplines? Would it mean the establishment of new research centers which are no longer organized along traditional disciplinary lines?

This volume presents another way of conducting research on the growth of knowledge, which crosses intra- and interscientific frontiers. This volume is a collection of the writings of Howard E. Gruber. In academic psychology, Gruber is widely known for his outstanding research on scientific creativity—in particular for his study on the development of Darwin's theory of evolution (Gruber 1974). It is thus tempting to subordinate Gruber's work into one of academic psychology's compartments, i.e. creativity research. But as the broad scope of Gruber's writings reveals, his work resists assignment to a neatly delineated research field. Apart from his contribution to our understanding of scientific creativity, Gruber *inter alia* worked on visual perception, on science education and—as a temporary collaborator of Jean Piaget—on cognitive development. Furthermore, he spent a considerable part of his productive energies on political issues, and so, for example, delineated an agenda for psychological peace research.

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Yet Gruber was not only an extraordinarily versatile man with wide-ranging scientific interests. As this volume aims to show, Gruber's multiple enterprises are integrated on the trajectory of an intellectual developmental course which, though surprising at first glance, is consistent and understandable. Standing at the crossroads of several disciplines, Gruber's detailed analyzes of the growth of thought as well as his way of approaching the question of how new ideas come into being make apparent the shortcomings that the disciplinary splitting of the topic of growth of knowledge entails.

At first sight, Gruber's work seems to fall into psychology's young field of creativity research. Considering the role, though, that social and cultural surroundings play in his cognitive case studies, psychologists might be tempted to push off Gruber's work into history of science. However, as Gruber's case studies address the development of thought, its structural make-up, the anatomy of conceptual changes as well as their preconditions, the questions that Gruber pursues are psychological. Following the borderlines of academia, they would fall within the range of developmental psychology. Moreover, if psychology took the challenge of situating the growth of ideas or thoughts culturally and historically, Gruber's work would form part of its disciplinary core.

In the following some of the fundamental lines of Gruber's approach will be presented by situating it within the field of creativity research. His perspective on creative work will be contrasted with two psychological approaches to creativity: the psychometric approach and the creative cognition approach. Secondly, it will be pointed out how Gruber's work can contribute to our understanding of the growth of knowledge.

## Roots and Principles of Psychometric Research on Creativity

Creation is a phenomenon that has attracted philosophers and scientists for centuries. Scientific discoveries or original works of art are surrounded by an aura of mystery as their production seems to surmount ordinary human capacities. The notion of *genius*, so prominent in European intellectual movements of the eighteenth and nineteenth century, mirrors this enigma of scientific or artistic invention and turns it into a particular quality of the creator. In its production, the *genius* doesn't imitate, it creates, it doesn't follow rules, but establishes them. To nature, the *genius* entertains an intimate relation: The comparison between natural generation and the productive forces of the *genius* was widespread in the eighteenth century. Moreover, *genius* was regarded as appertaining to nature. As "don de la nature," it could not be acquired through scholarly diligence. In his *Critique of Judgement* (1790), Kant defined genius as "the innate mental aptitude (ingenium) through which nature gives the rule to art."

Inaugurating the disenchantment of *genius,* Francis Galton can be regarded as the originator of the psychometric approach to creativity. His famous *Hereditary Genius* (Galton 1869) displays some of the basic assumptions of modern differential psychology (assumptions that Gruber repudiates): The person is conceived as composed of fixed situation-independent attributes, mental excellence being one of them. For the assessment of mental excellence, Galton isolated individual performance or even reputation—a feature whose dependence on social processes can hardly be overlooked—from their social embeddings and took them as expressions of the individual's stable characteristics.

In order to show statistically that intellectual excellence, as any physical attribute, is inherited, Galton adopted statistical tools from Quetelet, the most prominent one being the "law of deviation from an average," which later became known as the normal distribution. Measurement thus demanded its tribute: instead of describing the ways in which the creative person is extraordinary in its true sense, i.e. incomparable to others, "mental excellence" was reduced to a single dimension on which individuals are arranged according to their outcome in a series of comparisons. The set of interindividual differences thus determined the degree of mental excellence ascribed to the individual.

Comparing the distribution of the examination marks obtained by seventy-two applicants for the Royal Military College with the numbers predicted by Quetelet's law, Galton reported a good fit: Mental abilities showed the same pattern of variation as heritable physical attributes such as body measures. In order to provide even stronger evidence for the heritability of mental excellence, Galton analyzed the pedigrees of "eminent" English men such as judges or statesmen. If intellectual ability was inherited, his argument went, the number of eminent cases in the family of an eminent man should decrease with hereditary distance: Galton's results seemed to corroborate this hypothesis.

In his book on genius, however, Galton had to rely on examination grades in order to measure mental excellence quantitatively. Though a couple of practices assessing individual differences were common at that time, no scientific technique was available which would allow the researcher to derive assessment data suitable for statistical analysis. In his laboratory in London, Galton himself worked on the development of techniques which promised to measure mental "faculties." In the end, his mostly sensory tasks did not prepare the ground for the kind of investigation of creative abilities that was to come. The psychometric approach to creativity took over the methodology of the mental testing approach whose application in intelligence research had become paradigmatic for research on personality in general.

It is mentioned in most historical surveys on creativity research that it was only after World War II that psychologists realized the social demand for tools assessing creative potential. Both academic achievement as well as scores in ordinary intelligence tests turned out to be insufficient in identifying the ability to invent or to find solutions in new situations. But psychology had nothing much to offer: Research on creativity was scarce at that time. The few studies that existed were mostly in-depth examinations of insightful problem solving (Wertheimer 1945) or historiometric studies (Cox 1926), neither of which addressed the public need for selection tools.

Representing an accepted research tradition, both in academia and among the public, the mental testing tradition could serve as a model, providing methodological guidelines that helped to close this gap. Its fundamental presuppositions were taken over rapidly by creativity researchers: Creativity became an attribute that was stable across situations and domains. Instead of being ascribed exclusively to the few great creators, creativity was taken as a continuous trait that everybody had to a certain degree. These assumptions guaranteed that the measurement of creativity could take place in the standard fashion, i.e. by paper-and-pencil tests that were administered to a great number of people. Historically, the trait orientation of the psychometric approach to creativity may be explained by the diagnostic impetus backing its earliest steps. Creativity research at that time aimed at the identification and selection of people with high creative potential rather than describing creative activities in depth.

As will become clear in this book, Gruber's approach to creativity diverges from the psychometric tradition in several respects. In the psychometric approach, creativity is a domain-independent general-purpose ability that can be distilled from possible content. A person is creative to a certain degree, and his degree of creativity should show up in cooking in the same manner as in the elaboration of a scientific theory. Gruber repeatedly points to one of the general problems of the psychometric approach: The creativity measures that have been developed in this tradition show only poor correspondence to real-world creative achievement and suffer from a lack of validity. A further point of Gruber's critique is the questionable fruitfulness of the explanatory strategy launched by the psychometric approach to creativity. What can be learned about creative accomplishments such as scientific discovery or artistic invention—their possible origins as well as their genesis—if one just ascribes them to the high creativity of the creator?

A further problem is raised by the requirements of statistical data processing. As the creativity measures have to yield results that are amenable to statistical analysis, psychometric techniques require large samples and the researcher must lower selection criteria. Instead of confining his examination to the few prominent creators of the domain in question—as Gruber does in his case studies—, the researcher must increase the range of study in order to validate statements statistically: Thus individuals are included who may have been quite successful in their respective professions, but, as Gruber points out, most are far from revolutionizing their domain.

Psychometric analyses typically provide moderate correlations between the trait named creativity and intelligence, the number of siblings or the "openness to experience" scores on the "Big Five." Unquestionably, correlations like these can serve as clues to remote conditions of creative achievement. They may indicate that some sort of relationship exists between creativity and the features in question, but, as they do not aim at the creative process directly, correlations won't address Gruber's main interest: how creative work is actually done.

## THE CREATIVE COGNITION APPROACH TO CREATIVITY

A further tradition of research on creativity which should be mentioned in order to highlight Gruber's perspective on this notion is the *creative cognition approach* (for more recent publications see Smith,Ward and Finke 1995; Sternberg and Davidson 1995), in fact, Gruber refers to this line of creativity research in several of the papers in this volume. The creative cognition approach has its roots in *Gestalt psychology*. Köhler's description of insight (Köhler 1976), Duncker's study of problem solving (Duncker 1945), and especially Wertheimer's *Productive Thinking* (Wertheimer 1945) still form its groundwork. The approach has more recently been bolstered by methodological and theoretical tools adopted from the Cognitive Sciences. In contrast to psychometric research on creativity, work on creative thinking addresses the creative process itself. Studies in this tradition analyze thought processes leading to original ideas, to sudden insights or to representational reorganizations. Instead of taking creativity as a trait coming in grades or as a virtue pertaining to the very few, creativity is regarded here as an essential property of human thinking in general: The human mind is generative and so are its products.

The main purpose of the creative cognition approach is to analyze the structural underpinnings of creative thought processes. Here, creative thinking was shown to take place as conceptual combination, grouping, generalization, analogical reasoning etc. In order to lay bare the essential features of creative thought as neatly as possible, researchers often rely on experimental methods. In the standard setting, the subjects have to work on a task that requires some sort of creative invention—they have to solve classical insight problems, design new furniture, or construct a practical device out of given geometrical forms. Based on the results thus obtained, the cognitive operations applied by the subjects are then carefully examined.

In this kind of investigation, a similarity between creative cognition studies and the psychometric approach becomes apparent. In both traditions, the creative process is cut off from its possible content. The measures commonly used in the psychometric tradition assess "pure" creativity, and claim to disentangle creative potential from mere expertise or knowledge. In the studies of the creative cognition approach on the other hand, the anatomy of creative thinking is examined in the laboratory, i.e. in a sphere that is detached from the challenges of a real-life creative endeavor. A second point of similarity between the creative cognition and the psychometric approach is their generalist view of creativity. Creativity is either conceptualized as a universal characteristic of human cognition in general, or it is taken as a dimensional feature of different levels but in principle pertaining to everybody. Both the generalist grasp of creativity as well as the abstraction from the content of creative achievement diverge from Gruber's perspective on creative work.

Gruber studies the work of extraordinary individuals, unambiguous cases of creative accomplishment—"humanity at its best" (p. 272). Limiting the range of study to exceptional scientific creators and their work, Gruber's approach avoids the problem that afflicts ordinary psychological research on creativity, i.e. that of establishing valid external criteria for creative products. By not analyzing genuine creative accomplishments, both the creative cognition approach and the psychometric tradition must continually corroborate the validity of their findings.

In Gruber's studies of extraordinary creative individuals, the process of thought is seen in a whole person working under real historical circumstances. Since he aims to reconstruct the evolution of a creative accomplishment in the individual's actual field of endeavor, Gruber does not isolate the creative process from its object.

## GRUBER'S APPROACH TO CREATIVITY: STUDYING CREATIVE WORK THROUGH CASE STUDIES

Following Gruber's approach, we learn about creativity where it manifests itself most clearly—in the accomplishments of extraordinary creative people. Instead of assessing creativity through experiments or paper-and-pencil tests, Gruber recontextualizes creative work in *cognitive case studies*. A creative case study in Gruber's sense is directed at the whole person in full historical context. Conducting case studies in this vein imposes a heavier burden on the researcher, as it requires familiarity with the creator's domain as well as with the historical and cultural surroundings, i.e. it might require prerequisites that do not form part of the ordinary academic curriculum in psychology.

The focus of the case study is on the creative individual and his development rather than on basic components of short-time cognitive processes or on general indicators of creativity. It is suggestive to put this difference in terms of psychology's old controversy between nomothetic and idiographic methodology. Should psychological science formulate general laws that hold every time and everywhere, or should it carefully describe and reconstruct single facts, i.e. unique cases?

The concentration on the unique case that characterizes Gruber's approach to creative work might in part be motivated by a wish to "rescue the individual"; the decision to examine creativity in case studies of extraordinary creative individuals however should not solely be put down to philosophical convictions about the worth of individuality per se. Stressing the uniqueness of the case in question primarily sets a methodological guideline: Each person is unique in a unique way, and the case study reconstructs the unique organization of the course of the person's work. It thus aims to formulate a theory of the individual, as Gruber repeatedly points out. This objective is not met by just pointing to this or that extraordinary ability pertaining to the creative individual, to his supreme intelligence or his extraordinary musicality. The "theory of the individual" encompasses the unique "organization of the system, an organization that was constructed by the person himself in the course of his life, in the course of his work, as needed in order to meet the tasks that he encountered and that he set himself" (Gruber 1985c, p.177).

The case study method is backed by the so-called "evolving systems approach" which conceives of the person as a system of loosely coupled subsystems—knowledge, purpose and affect. Following this idea, a case study of creative work has to be situated at several levels. First, the path taken by the creator must be traced at the cognitive level. In a case study the creator's belief-system and its evolution within a certain time will be thoroughly reconstructed.

A second level of analysis is opened up by the field of motivation or, in Gruber's terms, by the creator's organization of purpose. Case studies of creative people usually address the person's development within an extended time span, i.e. the analysis will cover a period of several years rather than being confined to some brief moments of illumination. Due to this broad range, creative activity is manifest as work that must be directed and organized. The creator probably won't be absorbed by a single undertaking only, within the period at issue, he might pursue several strands of work whose interrelations have to be steadily orchestrated. Furthermore, he might have a vision or an idea—as inarticulate as it might be—giving his work direction. In thus revealing regulatory mechanisms such as the creator's network of enterprise or the initial sketch, the case study displays creative work as a purposeful undertaking orchestrated by the individual. Taking creation as the outgrowth of purposeful activity is to be contrasted to the romantic view of the creator as a vessel passively receiving his earth-shaking ideas either from God, the Weltgeist or from the arcane murmuring of his subconscious.

Gruber's perspective on the purposefulness of creative work also differs from the view of motivation prevailing in the research literature. In that view, creativity research was chiefly concerned with enduring attitudes to work and their probable impact on outcome. Are highly creative people striving for external rewards—success, fame, money—, or are they pursuing activities for their own sake, i.e. do they derive pleasure and fulfilment from their work alone? A creative case study, however, dissects a broad and generalized orientation such as "intrinsic motivation" and reveals the regulatory devices that the creative person relies on in order to organize and coordinate his undertakings and to keep his high commitment to work alive.

The third level of the creative case study is affect. In his studies, Gruber emphasizes the role of positive affects such as the joy of insight, courage, passion, or aesthetic pleasure. In particular, the case of affect demonstrates that knowledge, purpose and affect are not separated from each other and should not be treated as such in the case study. The creator's "initial sketch" can be taken as exemplifying the interdependence of the three systems. As a rough draft of the opus to follow—Gruber terms it the "gyroscope of the oeuvre"— it first provides the creator's work with a sense of direction, i.e. it acts as another regulatory mechanism on the motivational plane. The initial sketch also comprises *in nuce* basic ideas of the oeuvre to come later and is thus driving as well as guiding the evolution of the creator's belief-system. Lastly, the initial sketch might express some of the profoundest commitments the creator is attached to. The young Piaget's *Mission de l'Idée* exemplifies this affective aspect of the "initial sketch" vividly. It foreshadows one of Piaget's central ideas—*équilibration majorante*—but expresses it in the form of a poem that touches fundamentals of the human condition such as the meaning of life and transcending death.

Considering the primary aims of the case study method—the meticulous reconstruction of a single creator's development—, its orientation towards the work of the unique person, and its comprehensive scope encompassing the historical and the cultural context in which the creative individual is situated, the question arises: how does an endeavor like this differs from an ordinary historical study? Doesn't such an enquiry fall into the range of art history or history of science rather than into that of academic psychology? Can we draw any kind of psychological conclusions from a case study? Does its focus on the incomparable and extraordinary aspects of the person's creative development not rule out the possibility of deriving principles that hold for creative work in general?

As demonstrated in many of the papers to follow, immersion in a single case does not necessarily preclude general statements about the nature of creative activity. The purported trade-off between concentration on the individual creator on the one hand, and generalizations on the other is deceiving. First of all, there are now quite a number of creative case studies available that provide the opportunity for a psychologically oriented synthesis. Furthermore, the ideas Gruber introduces in his work distinguish his approach from ordinary historical analyses. Feldman et al. (1994) take the establishment of so-called "middle-level concepts" to be one of the most distinctive features of Gruber's case studies. Middle-level concepts such as the notion of a "network of enterprise" organize the abundant historical material of a case and thus can work as the researcher's analytical tools. But besides their function as methodological instruments, middle-level concepts display aspects of creative work itself: they grasp general features of the shape of a creative life without thereby reducing its complexity. Thus Gruber has developed concepts that represent and guide creative work, e.g. "network of enterprise" or "ensemble of metaphor." These concepts have emerged from Gruber's very close and detailed analysis of the creative work of his case studies. At the same time, these same concepts have also become methodological tools used by others in case study work.

Finally—and this point will be elaborated further in the pages to follow—, Gruber's work has implications for the psychological characterization of individual development, i.e. for theorizing about human development in a broader sense. First of all, looking at Gruber's case studies as well as his theoretical papers, it becomes obvious that his approach to creativity is developmental in orientation—developmental taken in a very specific way: Gruber does not focus on the average creative person's developmental trajectory, he does not aim to establish the developmental milestones for an "idealtypic creator," such as early emergence of specific interests, strong parental encouragement etc. Neither does Gruber restrict himself to a historical reconstruction of the genesis of the oeuvre itself independently of the person. Instead, Gruber analyzes creative work over a longer timespan: he looks at how the creative person purposely regulates his involvement with one or several enduring cognitive undertakings. Thus Gruber draws our attention to unique, self-directed and purposeful work, i.e. to a type of development often neglected by research on cognitive development.

Considering Gruber's beginnings as an experimental psychologist doing research on size and distance perception, there was hardly any indication either of his interest in creative development or of his later liaison with the history of science. When I asked him what drove a young experimental psychologist to start doing research work on Darwin, he answered something like: "Oh, I became interested in longer thought processes"—as if there was nothing more obvious in this case than to immerse himself in Darwin's notebooks! Of course, "longer thought processes" has a wide range of possible meanings in psychology. In experimental cognitive psychology thought processes extending over several seconds are exceptionally long, and a range of several minutes would make cognitive processes in most cases unanalyzable experimentally. Timespans of months or even years definitely transcend the limits of cognitive experimental research. Investigating thought processes of this range would force the researcher to switch domains and pass over to cognitive developmental psychology. And so it might have been no mere accident that Gruber started to become interested in the work of Jean Piaget. In 1955, he was invited to Geneva to give a talk on the relation between perception and cognition, but this short trip formed only the prelude of Gruber's later cooperation with Piaget.

## History of Science and Cognitive Development in Piaget's Genetic Epistemology and in Gruber's Approach to Creative Work

Gruber's cooperation with Piaget was long-lasting and productive. Gruber returned several times to the *Centre International d'Epistemologie Génétique* founded and headed by Piaget. One of the main aims of Gruber's stays in Geneva was the preparation of a one-volume extract of and commentary on Piaget's extensive oeuvre—*The Essential Piaget,* still one of the classics in developmental psychology.

Piaget's concerns and Gruber's interest meet in one important way: both of them work historically in order to answer questions arising from their psychological research on cognitive development. Piaget and Gruber both attempt to bridge developmental psychology and history of science, but they pursue this aim from fundamentally different perspectives.

Piaget laid the foundation of a comprehensive theory of knowledge. His *genetic epistemology,* intended as a kind of metascience, analyzes scientific knowledge from the perspective of development. This genetic approach provides the framework for the Piagetian connection between developmental psychology and history of science. Piaget's vision of genetic epistemology as a science conjoining historico-critical and psychogenetic methods is based on theoretical presuppositions that touch the relation between cognitive development and history of science. Ontogenesis and historiogenesis, according to this assumption, share functional mechanisms that give both developmental lines a definite shape. In Piaget's theory, development occurs as an ordered evolution of structures, with this structural growth process following a certain logic.

It is no secret that Piaget's main focus was on general cognitive structures. He was interested in the evolution of the universal epistemic "core" rather than in the individual and its development. *Creativity*, taken in the strict sense of the term, was thus not a main concern for him. Piaget may have considered the topic as a bit too hazy, too individual-centered and thus running counter to his goal to establish a general theory of knowledge and its evolution.

Highlighting the individual rather than the universal, Gruber's case study approach diverges from the perspective taken by Piaget. Gruber's emphasis on unique aspects of development, however, is no mere crude rejection of Piaget's "single-pathway" theory. Gruber provides fine-grained descriptions of processes of change and the theoretical framework guiding these patient reconstructions—the idea of a loose coupling between knowledge, purpose, and affect—puts into focus the role of the individual in development, an aspect somewhat neglected by Piaget.

Piaget's program of genetic epistemology transcended the confines of his early research on cognitive development in ontogeny. Following the generalized genetic approach outlined in the *Introduction à l'épistémologie génétique* (Piaget 1950c), the epistemologist has to understand both present and past scientific knowledge as functions of their specific developmental preconditions, instead of taking them as either timeless facts or as deficient precursors of later truths. For genetic epistemology, Piaget proposed a close cooperation between developmental psychology and the history of science, in his words between the psychogenetic and the historical-critical method. The historical-critical method traces the development of concepts such as number, space or time in history with the aim of comparing the structures underlying them. However, as scientific knowledge in its different historical stages already represents an advanced level of thinking, a historical-critical approach alone won't reach the point where knowledge and thinking originated. According to Piaget, it is the psychogenetic method that provides access to elementary stages of thinking. As an "intellectual embryology" it can describe forms of thinking that lie beyond the reach of historical analysis.

Piaget, though not adhering to a crude onto-phylogenetic parallelism, proposed a functional correspondence between ontogenesis and historiogenesis in his earliest publications and, as the posthumously published study *Psychogenesis and the History of Science* (Piaget and Garcia 1989) testifies, he clung to this view throughout his whole life. According to Piaget, conceptual development in childhood and the historical transformation of concepts share the same regulatory mechanisms.

The tendency to equilibrium—Gruber repeatedly mentions this idea in the following papers—is probably the regulatory mechanism that is most pronounced in Piaget's theory. Already the young Piaget claims to have found a *functional constant* of thinking. In *Logique génétique et sociologie* (Piaget 1928b), he takes mental formations in general to be products of an effort for systematization, an attempt to establish coherence taking shape in discrepant forms of organization, in different *structures*. According to Piaget these structures form stages of a single developmental process with a definite direction set by its functional determinant—*equilibration*.

In the *Introduction* Piaget postulates a similar functional principle common to historiogenesis and psychogenesis: both are characterized by a developmental tendency to reversible states of equilibrium. Piaget takes these forms of equilibrium as limits a genetic series converges to. Still in *Psychogenesis and the History of Science*, the assumption of developmental mechanisms operating both in ontogenesis and in scientific development provides the main methodological principle that guides the historical analyzes.

The universal functional mechanisms proposed by Piaget give conceptual change in history and in ontogenesis a definite shape. Cognitive development occurs as a progression from structure to structure, with each stage representing a form superior to its predecessor. To put it in broadest terms, during the construction of a novel structure the main features of the preceding level become integrated into the new structure, and are reorganized, generalized and projected at a higher level. The progressive succession of structures that thus emerges obtains a semblance of inevitability. As a given structure depends on the preceding levels and prepares the ground for those to follow, scientific as well as developmental innovations seem to form only components in a sequence of structures that as a whole is determined by universal developmental mechanisms.

In several of his papers on development, Gruber refers to this view as "logical determinism": "... the functioning of the logic of each stage determines the structure of the stage that follows" (p.325). The sequence of the different stages implies a "unilinear" model of structural evolution, one that precludes the individual's development along alternative pathways. As each stage provides the precondition for the structures to follow, i.e. for structures which are better equilibrated and have a broader range, Gruber holds that the Piagetian view of development is based on an idea of progress.

This structural account shapes Piaget's ideas of scientific change. In his writings on science history, Piaget does not analyze how the conscious, directed effort of an individual can contribute to conceptual innovation in science. Instead, conceptual change is regarded as a temporal disequilibration of a given structure, caused by its accommodation to new discoveries, and its succeeding reequilibration within a higher-order structure.

In several of his articles, Gruber repeatedly points out where his interests as well as his point of view differ from Piaget's theoretical commitments: "My own research and writing has for some time been centered on the creative process. *I have been interested in the unique rather than the universal*, leading me sometimes to speak disparagingly of one-track developmental theories such as Piaget's" (p.341). Considering Gruber's critique of the unilinear Piagetian model together with his emphasis on uniqueness and the idea of multiple developmental pathways (at least in adult development), a few catchy dichotomies seem to offer themselves: the individual vs. the epistemic subject, the unique vs. the universal, and plurality vs. unilinearity. But multidirectionality of development alone is not very original. The eminent role of the notion of uniqueness in Gruber's research reflects his interest in the meticulous reconstruction of processes of change—a topic somewhat neglected by Piaget. Describing the multiple configurations of ideas and strategies that emerge during the course of cognitive change requires the intense study of very few subjects over a certain time—that is why Gruber greatly appreciated the work of the strategies group headed by Bärbel Inhelder (Inhelder 1992).

The uniqueness of creative individuals, however, is not a mere fact. It may represent a developmental norm the creative person aims at. As Gruber repeatedly remarks in the following pages, the creative individual needs a set of personal resources in order to pursue his enterprises; he needs "the self and world knowledge necessary to move purposefully and effectively in a direction" (p.394). Personal prerequisites of creative accomplishments include strategies that guide the individual's work. Adopting an idea from cybernetics, Gruber speaks of deviation-amplifying systems that individuals might rely upon, i.e. "heuristics for identifying unusual ideas, recording them, and elaborating them" (p.356). Thus, Gruber points out that the person purposefully utilizes strategies and skills which move him away from pre-existing norms.

A perspective that takes creative development as self-directed brings aspects of creativity to light that are neither purely cognitive nor entirely motivational but which—to use Gruber's terms—mediate the system of purpose and system of belief. Gruber's work provides many examples for facets of this kind. The "sense of purpose" enables the individual to see each "sub-task in its place, as a part of the larger task he has set himself" (Gruber 1974, 113), the "point of view" denotes a perspective "from which new problems are seen and old ones are seen in a new light" (p.57). The "network of enterprise" or the "initial sketch" represent further cognitive-motivational facets of the creative process.

The idea of a self-directed course the creator takes in his work makes an important point for the psychological conceptualization of human development: In characterizing creative development as a process of "self-construction" (p.383), Gruber underlines the regulatory mechanisms the individual applies in order to orchestrate his work over long periods of time and, thereby, he shows creative development as a purposeful growth process rather than a quasi-natural unfolding of gifts or a unilinear sequence of stages.

The divergent accounts of development proposed by Piaget and Gruber could give the impression that both were fundamentally opposed and had nothing in common. Taking Piaget's perspective on the one hand, we see the epigenetic landscape from a higher point, and recognize the universal structural make-up of developmental processes. Gruber, on the other hand, invites us to delve into the complexity of development as it appears from the point of view of the individual. We recognize the large number of pathways open to the individual at a given point, as well as the strategies and procedures the person uses in order to stay on his chosen developmental track.

Both accounts, however, have commonalities that Piaget brings out in his foreword to *Darwin on Man*—Gruber's in-depth study of a scientist thinking. In this comment, Piaget highlights two aspects of Gruber's Darwin study. He emphasizes the slow rate of theory formation which shows that the construction of a new theory "necessitates an extremely complex structuring of interpretive ideas" (Piaget 1974b, ix). Furthermore, Piaget describes this structure-building as a reflective process during which schemas implicitly contained in already established cognitive formations are made explicit in a partly new structure. In mentioning these two aspects, Piaget underscores facets of Gruber's study where his own perspective and Gruber's account of Darwin's scientific development converge. Gruber himself, asserting the slow tempo of cognitive change, emphatically criticizes inspirationist accounts of creative activity. In his analysis of the growth of Darwin's theory of evolution, he shows that the idea of natural selection occurs in Darwin's notebooks before the celebrated "Malthusian insight" took place.

Finally—and this is where my comparison of Piaget and Gruber began—both sought to bridge developmental psychology and the history of science. Piaget as well as Gruber recognize history of science as a field that can serve as a source of material for developmental research. Thus, both approach the historical evidence with questions that differ from those usually pursued by historians. In addition, both men also attempt to demonstrate what developmental psychology has to contribute to our understanding of the course of scientific development, the historical growth of knowledge, and theoretical change.

## History of Science and Cognitive Development in Recent Psychological Theories

Gruber's and Piaget's endeavors to bridge developmental psychology and the history of science no longer stand alone. Now that developmental psychologists have discovered history as well as philosophy of science as fields of theoretical inspiration, scientific change has become a widespread model for the description of ontogenetic development in psychology—and quite a fashionable one too. The theory that goes the farthest in its theoretical borrowing from the history of science is the "theory theory" as propounded by Gopnik and Meltzoff (1997). The central tenet of this theory is "that the processes of cognitive development in children are similar to, indeed perhaps even identical with, the processes of cognitive development in scientists" (Gopnik and Meltzoff 1997, 3). Further cases of history of science-inspired theorizing in developmental psychology are not difficult to come by. Carey (1985; 1991) adopts Kuhn's doctrine of the incommensurability of disciplinary matrices and applies it to the description of cognitive development. Based on Kuhn's criteria for a conceptual change in science, she argues that children hold theories of matter, of weight, or of living things that are incommensurable with the adults' theories. Frequently, the "theory" notion in psychology is coupled with the idea that cognitive development proceeds domain-specifically. Wellman and Gelman (1992), for example, reject general logico-mathematical structures or components of the cognitive architecture as possible factors accounting for knowledge organization and for developmental change in thinking. Instead, they posit content-specific systems of knowledge in domains such as physics, psychology, and biology that provide persons with basic ontological distinctions and explanatory principles. Wellman and Gelman (1992) term these foundational knowledge systems "framework theories"—a notion they liken to Kuhn's paradigms or to Lakatos' research programs.

Piaget is often accredited with having coined the image of the child as scientist. However, the range of this attribution is limited. Admittedly, Piaget held the view that children, like scientists, have to actively explore their environment in order to learn. But beyond this anti-empiricist truism, the alleged historical continuity between Piaget and the "theory theorists" is misleading since it veils the divergent epistemological presuppositions underlying each approach.

Piaget's concern for the evolution of the sciences was not prompted by some idea of transferring methodological or descriptive instruments from philosophy of science to the study of cognitive development in children. On the contrary, as mentioned above, his genetic epistemology entailed a comprehensive study encompassing the growth of knowledge both in history and in individual development (Kitchener 1986). In Piaget's theory of knowledge, mechanisms such as equilibration or reflective abstraction provide the analytical framework for an undertaking of such dimensions, since those factors are assumed to operate in both developmental lines and thus render it feasible to trace their course with a unified theoretical framework.

The "theory"-inspired developmental psychologists on the other hand adopt scientific theories as models for children's knowledge. Children's understanding of persons or their interpretations of natural phenomena are based on knowledge structures which involve theoretical constructs, such as beliefs and desires, or concepts of unobservable entities. These theory-like knowledge structures are lawfully interrelated, are thus coherent, and can fulfill explanatory and predictive purposes.

The theory theorists assimilate the development of children's cognitive structures to theory dynamics. For the case of theory dynamics in science, Gopnik and Meltzoff (1997) propose an account of theory change that is supposed to provide a condensed version of the relevant philosophical literature: Proponents of the old theory first deny the empirical counterevidence, but later attempt to save the theory through the construction of ad hoc hypotheses. Finally, the new theory emerges—often as an extension of an idea that was already implicit in the earlier theory. Gopnik and Meltzoff maintain that this sequence should also take place in cognitive development. Children systematically strive to apply their intuitive theories to a wide range of situations. Their aim for consistency, though, occasionally blinds them to the facts. Sticking to the central ideas of their intuitive theories, the children—at least for a certain time—resist counter-evidence.

Most of the "theory" accounts of cognitive development work with an idea of "scientific theory" which should represent something like the least common denominator of the widely differing "theory" conceptions to be found in philosophy and history of science. Yet a couple of the features taken as defining criteria for theories by developmental psychologists are adopted from the so-called "standard view" of scientific theories as propounded by authors such as R. Carnap or C. G. Hempel (Suppe 1977). Examples of takeovers from this tradition are the emphasis on the dichotomy between empirical evidence and theoretical constructs, or the idea that theoretical coherence results from lawful interrelations among theoretical concepts. Another source of inspiration for the "theory theory" is the work of the "undogmatic" empiricist W.V.O. Quine. Susan Carey's idea that concepts should be identified with the roles they play in theories (Carey 1985; 1991) undoubtedly embraces Quine's semantic holism, but couches it in a cognitivist vocabulary. Gopnik and Meltzoff themselves underscore the extent to which their concept of knowledge was shaped by the Quinean idea that our beliefs form an interconnected field which touches experience at its margins (Quine, 1951).

Endorsing the Quinean tenet of theoretical underdetermination, Gopnik and Meltzoff reject the view that experience alone might uniquely determine theory choice. How then does the scientist cope with the immense range of possible hypotheses that are compatible with the available evidence? Gopnik and Meltzoff advance an evolutionary explanation: "There are constraints on the kinds of theories human minds will construct, given a particular pattern of input. We can think of these constraints as embodying implicit assumptions about the way the world works. The truth of these assumptions is, in some way, guaranteed by evolution" (Gopnik and Meltzoff 1997, 216). Humankind—scientists and children included—is built so as to get things right.

The philosophical orientation of the theory theorists, however, raises problems for a psychological and historical analysis, as neither the "standard view" of theories nor Quine's picture of a web of statements intend to provide a realistic, i.e. a psychologically valid account of scientific thinking.

The "standard view" of theories was an outgrowth of the positivist "rational reconstruction," the epistemological and at least partially normative analysis of scientific knowledge. Presupposing a rigid distinction between "context of discovery" and "context of justification," the logical positivists could push the examination of actual scientific thinking into the somewhat dingy corner of discovery, which they left to psychologists or sociologists. Quine's (1951) picture of a web of belief, on the other hand, provides at most a framework for an empirical study of knowledge and its change, but is far from settling the question of how scientists, ordinary people, or children conceive the world and how changes in these conceptions occur.

Hence, neither the "standard view" of theories nor Quine's work on the relation between semantics and knowledge were aimed at the individual scientist's representational mechanisms or at the cognitive strategies used in tackling particular problems. Both were epistemological accounts that did not address the question of what "theorizing" looks like at the level of the individual scientist. That is why the criteria by which "theories" are defined in the "theory" accounts of cognitive development—coherence, dichotomy between theory and evidence, explanatory and predictive functions—seem to vacillate between the psychological and the normative, with the latter providing an explication of theories from an epistemological perspective rather than a valid psychological analysis.

The drawbacks of the "theory" accounts become evident when one considers Gruber's thick description of the discovery process. At first glance, the idea of scientific discovery as a sequence of theories seems to capture Gruber's case studies of Darwin's theoretical development quite well. As can be seen in Figure 1 (p.129), Gruber describes the changes in Darwin's thinking between 1832 and 1838 as a sequence of stages in an increasingly complex belief system. Reading Gruber's reconstruction more carefully though, one notices multiple aspects of Darwin's thinking during that time which, albeit playing major parts in the construction of the theory of evolution, are missed in the picture of scientific thinking presented by the "theory theorists." We see a young Darwin who skillfully used ambiguities to explore alternative pathways of thinking. We learn that between 1835 and 1837, Darwin created a peculiar style of thought which allowed him to push ideas to their limits. As the *Red Notebook* reveals, Darwin, in this period, tended to focus on extreme scales, both on the very small and the very great. By steadily making out possible great effects of accumulated small events he was able to relate both extremes. In *The Emergence of a Sense of Purpose* (p.123-144) and in *Going the Limit* (p.145-166), Gruber describes several thought-forms that Darwin developed at that time. One of them is the *equilibration model* which holds that every natural phenomenon tends to oscillate around some value. When the deviation is too great, a regulating process re-establishes equilibrium. Another form of thought that Darwin utilized was to situate every particular phenomenon within the whole range of processes belonging to the domain at issue. Recurring to a concept from the cognitive sciences, thought forms and thinking styles of this kind could be regarded as heuristics operating in the discovery process.

Gruber emphasizes repeatedly that the experience Darwin gained during the Beagle voyage was far from sufficient to account for his intellectual development leading to the theory of evolution. So Darwin too faced theoretical underdetermination. Gruber stresses that between 1832 and 1838, during the phase of theory construction, "Darwin seems to be moving in a direction, making a set of choices, constructing a point of view and applying it over a whole range of phenomena" (p.154). It seems that Darwin found his way of dealing with underdetermination. Yet instead of crediting evolutionary constraints with this accomplishment, Gruber's analysis displays the multiple origins of Darwin's "constraints on theory building": Part of them are due to the "shared knowledge" which Darwin took over from family traditions as well as from the "historical currents to which he was exposed" (p.164)—Lyell's *Principles* is a case in point here. But partly the "sense of direction" guiding Darwin's theoretical development during 1832 and 1838 arose from the particular style of thinking which Darwin created at that time. In the papers on Darwin included in this volume, Gruber unfolds the multiple facets of this "style of thinking": Darwin's various "thought-forms," his preference for going to extremes, the way he fruitfully used ambiguities, the metaphors he was working on etc.

Perhaps the strongest tenet of the "theory theory" is the assumption that the psychological processes operative in children's cognitive development are identical to those underlying theory change in science. Gruber's account of creative development casts doubt on this claim. Gruber depicts creative growth as a purposeful process guided not only by the "sense of direction" but also by the creator's "sense of the self." This idea does not mean that the creator is a self-absorbed narcissist. "Sense of self" refers, rather, to the artist's or the scientist's commitment to his chosen task: to his goals and to a realistic estimate of his resources. Whether cognitive development in childhood can be described as a purposeful process in this sense is doubtful. Certainly, one might find forms of self-regulated cognitive development in adolescence, a phase during which the person builds up the first high-level commitments and long-ranging interests. But describing cognitive development in early and middle childhood as a purposeful self-regulated process in Gruber's sense would be inappropriate. During this phase, "child development moves the individual toward pre-existing norms" (p.350)—either by Piagetian autoregulative mechanisms, by enculturation or, following the recent theories on infant cognition, by innate constraints.

Is thus the main conclusion to be drawn from Gruber's account of scientific discovery that historians of science and developmental psychologists work in separate fields which should be kept distinct? Should we thus bolster the disciplinary boundary between history of science and psychology instead of rendering it more penetrable? The opposite is true. Gruber's case studies are genuine psychological analyses of long-term processes of thinking and are developmental in orientation. Instead of merely providing intuitive narrative accounts of developing ideas, Gruber describes the cognitive structures and mechanisms, i.e. the tools used in scientific thinking, and thus offers in-depth analyses of creative development. But in contrast to many models developed in cognitive science laboratories, Gruber's studies take the cultural and historical determinants of scientific thinking into consideration. Cultural and historical determinants do not simply include some distant factors of influence, but instead refer to the knowledge structures available in a given culture. Gruber shows how the knowledge of an individual partakes in the currents of the social knowledge available at a certain time, and points out how the development of an individual can be situated within a cultural system of knowledge. Gruber's case studies thus demonstrate that both historical analysis and psychology are indispensable in understanding creative development.

Berlin, August 2004 Katja Bödeker

# INTRODUCTION

*The mind of man is framed*
*Even like the breath and harmony of music:*
*There is a dark invisible workmanship*
*That reconciled discordant elements*
*And makes them move in one society*
—William Wordsworth, *The Prelude*

## A LIFE WITH A PURPOSE

The process of science entails a paradox. On the one hand, the scientist must develop and nurture a point of view that facilitates and encourages the discovery of novelty. On the other hand, this point of view, while assimilating the new, must also be stable enough to preserve its own direction and continuity. In going through Darwin's notebooks, I could see both sides of this paradox played out, sometimes in the same passage.

Scientific thinking, even in its most exhilarating moments, is a highly organized process. It builds upon a framework that orients and directs but also confines the scientist's intellectual activities. Noticing relations between facts or events entails a new perspective and a point of view. Formerly unrecognized evidence, for instance, must be incorporated into the existing structures of thought. Openness to the new, therefore, rather than representing a general and limitless habitude, depends on the nature of the structural configuration at a certain point in time. Thus, on the one hand, the existing structure protects itself from elements that might lead to a structural change and, on the other hand, is subject to the compelling attraction of novel information. Such new material may provoke intriguing thoughts, digressions, and deep immersion, thus jeopardizing the continuity and integrity of the scientist's original endeavors. In order to preserve coherence and direction, the scientist must step back and examine the new material as part of his long-term undertaking.

It seems obvious that the history of science provides an excellent, perhaps the best, source of materials for a psychological study of scientific thought. This inquiry might fruitfully integrate the two disciplines of psychology and the history of science. The goal of such an endeavor would be to link the reconstruction of the scientist's intellectual work to some general assumptions about the development of thinking in its historical contexts. Unfortunately, neither the established methods of theory construction and hypothesis testing as they are practised and vehemently advocated in psychology, nor a merely biographical tracing of the life-course of the

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creative scientist seem particularly suited to fostering such a synthesis between psychology and history (for a promising alternative see Gooding 1990; Hanson 1958; Kuhn, 1962).

In psychology, there have been numerous studies of scientific thought, but few of them take a historical approach. Even a classic like Max Wertheimer's *Productive Thinking* (1945) is an ahistorical treatment of its subject, treating as essentially the same two children playing badminton, a secretary thinking about her office, Galileo and Einstein thinking about physical problems. Such a monistic approach might plausibly have some value but it loses the vitality that historical inquiry must have. The prevalent convention of refraining from historical analysis and psychology exclusively focusing on processes may have acted as a hindrance to the study of scientific thought or scientific creativity. In their search for the general mental operations underlying creativity, cognitive psychologists are often at great pains to expunge meaning from the empirical investigation of thinking, presenting their subjects with content-free "stimuli" such as geometrical figures or trying to isolate the test material from the person's actual field of knowledge. Even if the attempt is made not to detach thinking from its content, the focus of study is usually on the simple occurrence of creative ideas rather than on their structure or their position within the person's broader framework of knowledge (for a good review of experimental research in this tradition see Runco and Sakamoto 1999).

Psychometric studies addressing the relation between personality and scientific work also suffer from a similar absence of real content. In order to demonstrate statistically how personality might affect creative achievement, large samples of subjects are needed—a requirement that will inevitably downgrade the criterion level on which creative individuals are chosen. Furthermore, the study of large numbers of subjects, together with the high level of abstraction that it dictates, will force the investigator to disregard the very specialized skills and knowledge that may represent the bedrock of the individual's creativity. Psychometric research of scientific creativity thus aims at very general conclusions (e.g. that creative scientists tend to be more ambitious), behind which the content and inner structure of the individuals' particular work disappears (see Plucker and Renzulli (1999) for a good review of research in this tradition).

The investigator of creativity seems, almost inevitably, to pass through a phase of constructing a system of categories, e.g. *Preparation-Incubation-Illumination-Verification* (Wallas 1926); *Person-Process-Product* (Stein 1968); *Field-Domain-Person* (Csikszentmihalyi 1988a, 1996). My humble contribution to this categorizing is to emphasize that three features found in extraordinarily creative people—*Knowledge-Purpose-Affect*—are essential for understanding the development of creative work.

Certainly the making of categories and, more generally, taxonomic behavior is part of doing science. But categorizing is not enough, especially if it entails neglecting the processes that give rise to the categories. As Darwin put it, in discussing a similar methodological point, we have to go beyond "the mere putting together and separating objects more or less alike" (Darwin 1859, 420).

A fundamental premise of the *evolving systems approach*—our approach to the study of creative work, which is represented in the first section of this book—is that every creator is unique and is so in just those ways that are essential for the particular tasks confronting him or her. These are often tasks that owe their origin and urgency to the efforts of the creator in question. Such a perspective makes it useless, not to say harmful and misleading, only to search for general laws governing creative work while neglecting each individual creator's efforts.

For example, let us consider, or reconsider, the often-cited case of Kekulé's discovery of the benzene ring in a reverie of the dance of atoms (for a challenging and skeptical account of this story see Wotiz 1993). As Kekulé told the story much later in his life, it is a classic case of an apparently involuntary sudden insight occurring during a hypnagogic reverie, an episode largely devoid of conscious intent, careful planning, rational thought, or collaborative work. Yet it is exactly these characteristics that are the salient elements in the tale, elements that only become apparent through detailed study of the whole case. Without a body of such studies there is little merit in counting up numbers of occurrences of sudden insight. But what does even "a body of such studies" provide? Only at a rather lofty level of abstraction can we say that Darwin's sketches of the irregularly branching tree of nature have something in common with Kekulé's reverie of the dance of the atoms. And to attain the necessary level in our own thinking we need in-depth studies of both Darwin and Kekulé, one a biologist, the other a chemist, together with a conceptual exploration of imagery in scientific thought. Following a line of thought similar to mine, Arthur Miller has, in one telling page, expressed his doubts as to the legitimacy of lumping together insights that occur within very different lines of thought. (For more on this, see Gruber 1995b; Miller 1984).

Thoughts such as these led my collaborators and me to our heavy reliance on the case study method as the appropriate road to travel. A cognitive case study in scientific thinking can be seen as an attempt to synthesize the analysis of the processes of thought with the reconstruction of its content. In scrutinizing the individual's cognitive organization as a whole, studies of the development of single scientists try to shed light on the inner workings of creative minds.

In our search for the appropriate level of analysis, we have found it useful to avoid choosing one favorite level as the "best." A more fruitful approach is to single out several levels of analysis appropriate for the given case, and then strive to fit them together. Although my own studies of Darwin's creative work did not explicitly aspire to this interplay of levels, to some extent the approach did work its way into *Darwin on Man* (1981e).

## LEITMOTIFS

### *Network of Enterprise*

Following Herbert Simon's approach, explaining scientific creativity in terms of problem solving, cognitive studies of science are still prone to regard creative work as puzzle solving, as a mere cognitive striving to discover answers to already recognized questions. Implicit in this approach is the image of a problem or a task as an external situation that faces the scientist, as well as the idea of the solution as something that exists and is simply to be grasped. The description of scientific activity thus turns into a retracing of its search.

Problem solving certainly is a vital constituent of scientific work, but it should be situated within the context of a larger set of cognitive processes which the individual must orchestrate.

The most distinctive feature of the *evolving systems approach* is our emphasis on the idea that creative work is purposeful and that it takes time because it is in principle difficult, and almost always follows a meaningful but non-linear course. The creative person has many purposes; they vary in scope, in intensity, in immediacy, and in privacy. Activity is split up into many strands, the coordination and regulation of which is not given to the person but is to be constructed in the course of working and living. In order to depict this complex and long-term organization of work we have put forward the concept of a *network of enterprise.* This idea can be considered as one of the *leitmotifs* of our study—a recurrent theme disclosing the consistency underlying the considerable diversity of our projects and activities.

We take an *enterprise* to be a set of projects and activities the creative person pursues for a long time, sometimes for decades. Due to its tendency to become self-perturbating, an enterprise hardly if ever comes to an end: When a goal is attained, the enterprise is likely to engender novel tasks and projects that continue it. The creative individual does not pursue only a single enterprise, but orchestrates and coordinates several, thereby constructing the *network of enterprise.* The network enables the creator to maintain parallel enterprises or to switch from one enterprise to another as the work demands. Over time, the form and content of the network may change. But far from representing a silent process of gradual modification, the change is actively initiated and controlled by the individual. The creative person possesses a repertoire of strategies that transform current patterns of activity, e.g. *branching* one enterprise into two or more or, inversely, *merging* several enterprises into one. If there are several enterprises in the network, they almost certainly are at different stages at any given time—a point that has been largely neglected.

The *network of enterprise* is also a methodological tool for the researcher that provides a direct way of schematizing and describing the creative person's entire set of intentions and endeavors. Our initial assumption was that such a network would simply give us a picture of the creator's intentions as an array of projects organized in time, a sort of skeletal description of what the person had done, is doing, and plans to do in the future. But it has become apparent that the *network of enterprise* also reflects deeper motives and long standing commitments—ideological, intellectual, and aesthetic. The few sketches we provide are faithful to the modest goal of skeletal descriptions based on actual projects, each strand of the network representing a line of endeavor. The network as a whole stands for the creator's oeuvre.

This way of describing an oeuvre does not impinge upon or impair other approaches to motivation, such as the *Zeigarnik* effect (Zeigarnik 1927), which emphasizes task interruption as a dynamic force in the development of specific works, or Maslow's need hierarchy (1966) situating particular lines of effort in the lifetime as a whole. Indeed, these ideas are often demonstrated within the *network of enterprise*. Zeigarnik's experiments suggest how the creator becomes increasingly invested in the whys and wherefores of his or her own work.

Although the creator's ways of working may sometimes resemble other obsessive processes, it does not originate from pathology but from intense interest in the world and, occasionally, from efforts to change it. My approach may seem too rosy, especially as compared to approaches to creativity focusing on psychopathology. But this gulf between normal and abnormal is misleading. There is no reason to think they are mutually exclusive. Take Van Gogh, for example. Of course he suffered from some pathological condition. But this statement must be tempered. First, when he painted he was always lucid. Second, his famous letters to his brother Theo represent a very sane mind. Incidentally, he did not cut off his ear, he only mutilated it: not edifying, but a much less violent act than the one usually attributed to him. Furthermore, it may well be that Van Gogh's illness was caused by his repeated exposure to the poisonous heavy metals used in making some pigments, not the dynamics usually implied by theories of psychopathology.

The creative person's *network of enterprise* makes a vital contribution to his or her sense of self: On waking after a sleep, personal consciousness is continuous. The purposeful creator immediately knows who he or she is and what must be done next. There are many ways to follow, but the creative person is not taking a random walk through these possibilities; deviations from the prevailing systems of belief must be explained or justified—and that work, we have found, takes time, much time.

It is the pursuit of these enterprises that makes up a productive life so that if the inventory of unfinished tasks were ever to go to zero, the person would bend all his effort to replenish it. In reality, of course, such enterprises are hardly if ever exhausted. For clarification it should be added that there is no reason to assume *a priori* that a large network is more creative than a small one. This point applies to all the many ways that branching structures can vary or differ. There would be little point in collecting many such structures in the hope of correlating some variable of branching structures with some variable of the creative person or process. Indeed, that might defeat the purpose of the tree metaphor by diverting attention away from the effort to construct a model capturing the uniqueness of each creator.

I still relive the thrill of discovery when I move my gaze upward from the diagram itself (See Figure 1.) to the caption Darwin gave it: "I think."

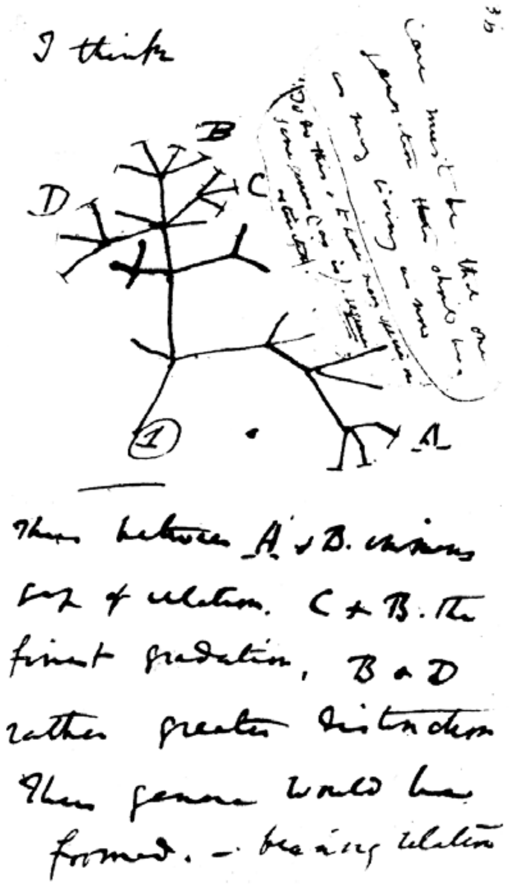


*Figure 1.* Darwin's early attempts to sketch the idea of the irregularly branching tree of nature (Reproduced from Gruber 1981e).

Finally, each creator assembles the enterprises that form his or her tree. They are not invented and supplied by the investigator of the creative process. It is the creator who constructs and discovers the branches.

*Pluralism*

Over time, *pluralism* emerged as a conscious theme guiding my understanding of intentional creative work—a second leitmotif helping to give our work its identity. Coming into focus as the result of some recurring ideas in our creativity studies, the motif itself was foreshadowed in the scepticism concerning monistic accounts of thinking as it is apparent in my work on perception. The aim of these early studies, however, was not to prove the plurality of cognitive modalities, but rather to display the problems and requirements that arise from them. In order to scrutinize how continuity of thinking can be preserved in the face of this diversity of modalities, we began to explore *transformations* that integrate distinct cognitive events.

One focus of our research on creativity is the issue of *uniqueness*, a theme which both constitutes an assumption concerning the shape of a creative life and an imperative about how to study it. Neither the progression of a fixed sequence of stages nor the unfolding of innate gifts provide an appropriate model to describe creative development. A creative life takes no standard course—there are many different paths to Mount Olympus. The creative process is intricate and multi-faceted. Every scientific effort opens up a number of potential pathways for future investigation; the individual must find ways of coping with the danger of vacillation and pseudo-growth. Yet the creator is not trying out this and that in cavalier fashion. Even with some or much time and space for play, the main acts in a creative process are purposeful, serious activity. Interesting change-making is neither haphazard nor linear. It is an orderly process of exploration, experimentation, and reflection directed towards keeping the individual on his course of productive achievement. The *network of enterprise* is in part a regulatory mechanism, giving the creative person a *sense of direction* and a vision of what he strives for. Again, neither the mere existence of multiple developmental pathways *per se* nor the various turns and twists of a creative life are the targets of our research on creativity, rather we wish to understand the requirements and adaptions which lead to this pluralism. I interpret my own and others' studies of repetition and transformation not as revealing conservative moves, but as showing more clearly how creative change can be both orderly and innovative.

For the investigator, *pluralism* is liberating because a single entity does not have to bear the weight of the whole. But plurality also means that more must be mastered, related disciplines must be accommodated and, so far as possible, the work of synthesis must go forward. When studying the creator's work over time, it was clear that there was not one grand enterprise but several; not one ruling metaphor but an ensemble of metaphors; not one grand insight springing up in isolation from its context but a host of insights both expressing and guiding the sweep of the work.

## ORGANIZATION OF THE BOOK

The present book is a collection of my papers ranging over a period of some forty years, from 1959 to 1999. Although I am the main author of the papers in this book throughout most of the decades represented here, I have benefited profoundly from the collaboration of a shifting group of students and colleagues. The free use of "I" and "we" reflects this state of affairs.

The collection has two main aims: First, we seek to bring out the mutually enriching relations between the history of science and the psychological study of thinking and thus try to foster and demonstrate the possibility of a synthesis of psychology and the study of the sciences—our research on creativity can be understood as an outgrowth of this endeavor. Second, the book is intended to illustrate my own efforts to combine a career as a working scientist with a career as a concerned citizen.

Presenting our work as it evolved within a forty-year period, the book is not organized in a linear way, it shows no step-by-step development of a coherent ensemble of ideas. Such an arrangement would run counter to the picture of creative work that is propounded in the papers to follow. We compare creative work to a network of multiple strands that cross, merge, and branch in a unique and unpredictable way. The arrangement of this book is inspired by this *network of enterprise* idea. The book is divided into eight sections, each including articles representing one of the enterprises I pursued throughout my working life. I hope that this arrangement permits us to see one *network of enterprise* as a whole, while preserving the elements that compose it.

This kind of arrangement implies that the book has no preset direction of study. The reader is not expected to proceed straight from cover to cover, but should cut her own path through the book and feel free to begin where her field of interest lies. Subsequently, she can follow the thematic lines running between the different sections. Thus, the reader's path through the book won't resemble a straight line, but more the *branching tree of nature*, i.e. the image that is so prominent in our account of creative development.

As the collection does not conform to a unilinear unfolding of thoughts, some of our preeminent themes will emerge, slightly varied, in several thematic sections of the book. These recurrences uncover on the one hand the sub-surface connections running between our different fields of activity and on the other indicate the variations and modulations those themes undergo when transposed to various fields of application.

The issue of the *nature of thinking* can be taken as one of those themes. It elucidates the continuity underlying the seemingly disparate strands of my work and thus integrates the different sections of this book.

*How much time does thinking take?*

Following their methodological *credo* to analyze and isolate mental events experimentally, cognitive psychologists, in their study of thinking, mostly concentrate on cognitive processes of a narrow temporal scope. So did I in my early experimental work, when I dealt, for example, with the cognitive underpinnings of causal impressions or perceptual organization. But obviously, cognitive events falling within the range of milliseconds form parts of larger sequences of thought that extend over weeks, months and even years. The thought process that I sought to trace in my cognitive case study of Darwin's development of the theory of evolution can be conceived of as such an intricate long-term event.

In our research on creative work we aim at cognitive processes on this broad timescale. One of the main results of our studies is an appreciation of how much time it takes to do creative work and an understanding of the requirements that it brings with it. In the pursuit of a cognitive long-term endeavor, the individual faces the danger of going astray. While deviating from a previously chosen path is necessary if the person is to exploit fully the surprises and new problems discovered, it is also important to develop regulatory capacities to keep such deviations within bounds. The *network of enterprise* and the *sense of purpose* provide the individual with a regulatory system to remain on the pathway to productive achievement.

Both the creator and the investigator of creative work must have stamina: They must contend with different branches of knowledge, different styles of thought, and the different historical moments at which each drama of discovery is played out. A key problem in such an effort is to find ways of dealing with the elements without losing sight of our ultimate goals—to understand something about both the forest and the trees. Our work on the creative process, its development as well as the requirements that it entails is depicted in the first section of the book, *The Creative Person as a Whole.*

The scientific concern for long-term processes of thinking could and should be pursued as a joint undertaking of two disciplines—with the history of science supplying the source material and cognitive psychology providing some general ideas about intellectual processes. When I began my case study of Darwin (some of the results of which can be found in the second section entitled *The Man Who Started It All*), I hoped to bring together both fields of inquiry to a fruitful new synthesis. However, I soon realized that this endeavor was extremely difficult. Besides the understanding of biology and geology that a study of Darwin's notebooks necessitated, I found that neither the organization of psychology nor that of the history of science fostered such an interdisciplinary undertaking. Separated by a formidably high disciplinary wall, fragmentation and atomism dominated the scene. This picture has changed over the last twenty years as the result of a number of excellent case studies on the structure and the development of the creative process. But part of my original difficulties remain: The history of science and psychology represent, in organization and in culture, two distinct disciplines. In addition to their disciplinary boundaries, the degree of intradisciplinary specialization, at least in psychology, is very high. Every year, new research journals are established and new professional organizations are founded, representing the emergence of new fields of psychological research. Given that this disciplinary branching might demonstrate scientific vigor, it could ultimately turn the discipline into a conglomeration of small communities within each of which communication is intense but with hardly any scientific exchange among them. In any case, this process of scientific splitting demands a high degree of specialization. Approximately at the level of advanced university training, the student normally encounters institutional and scientific constraints that force a narrowing of interests and pressure to find a place in one of the many sub-communities. Changes of scientific concern or a serious ambition to bring disciplines or even sub-disciplines together are not only difficult to pursue but might represent, from the point of view of the individual's professional interests, a risky undertaking. Intradisciplinary organization as well as interdisciplinary frontiers thus may turn out to impede scientific innovations, which produce a rearrangement of the scientific landscape.

The image of creative thinking portrayed in the first two sections of the book is that of a protracted non-linear process. To describe the creative process as non-linear, however, refers not only to the web of projects and enterprises, but to the *temporal shape of creative thinking*—an issue addressed in the papers of the third section, *Facets of the Creative Process.*

Many models of the creative process make implicit assumptions about its temporal structure, the most prominent among them equating creative thinking with the occurrence of sudden insights: In this conception, insights occur like lightning bolts out of the blue and instantly re-arrange the individual's mental structure. Wallas' famous four-step model of creative thinking *(preparation, incubation, illumination, verification)*, however, considers these *Aha-experiences* as stages in a long-term development and, taking a stance akin to ours, examines their position and function within this process. But unlike our approach, Wallas' four-stage model is linear. The model also tends to conceal the protracted temporal structure of the creative process with its multiple temporal layers and nested levels. An insight, for instance, can be conceived as a temporal compression of extended thought processes or as a long-term development of thinking telescoped into a few seconds.

Embracing this view of insight as a *re-cognition* of what one already almost knows, rather than an emergence of entirely new ideas, makes apparent that repetition, contrary to psychological folklore, forms a vital part of the creative process. In general, the role of repetition in the psychology of thinking is marginal at best, mostly mentioned as a correlation between frequency of repetition and adequacy of recall or simply as a destructive activity. In problem solving research, repetition is simply out of place. If a problem being solved is presented again, it will initiate a retrieval of the solution rather than a novel trial to work it out. Of course, nothing is ever repeated exactly. Repetitions generally give rise to slight variations of the performance of an action or even of its underlying organizing structure, thereby both consolidating and elaborating it. We therefore stress the *constructive function of repetition.*

Following the temporal structure of thinking (the main topic of the third section), section 4, *Modalities,* is concerned with the stuff of experience, i.e. with different modes of representation and their interplay. Individuals have at their disposal a number of modalities of representation, e.g. systems of taxonomies, propositions etc., the interrelationships of these, however, as well as their role in the cognitive economy taken as a whole, are hardly understood. Imagery is one of the main issues to be addressed in this section. By now, imagery has turned into a prolific research field in psychology which, with the adoption of the new brain imaging techniques in the cognitive sciences, is even enlarging. Though covering a wide range of cognitive phenomena, the study of imagery deals predominantly with very concrete images, that can be conceived of as veritable *residues* of perceptual experiences—such as Galton's breakfast table or your spouse's face. In our work, however, we focus on a different aspect of imagery, namely the role of *images of wide scope* in creative thinking. Different from the quasi-perceptual objects of cognitive psychology, *images of wide scope*, in contributing to the generation and exploration of ideas, form an integral part of creative thinking. They are eminently flexible and generative, and like Darwin's tree, can represent the multiple meanings, unexpected aspects, and relationships of an idea being unfolded. *Images of wide scope* are further mechanisms regulating the creative process.

Due to its concern with long-term processes of thinking and their regulation, our work can be understood as falling within the range of developmental psychology. The different aspects of this relationship are to be explored in section 6 and 7, *Tracking the Ordinary Course of Development* and *Coping With the Extraordinary*.

In our cognitive case studies we attempt to grasp an individual's cognitive economy as a whole, and in order to do so, we have found it useful to think of the creative person's thought as a set of developing structures. Thought evolves in structures: The person works with one such structure, elaborates it, recognizes its shortcomings and transforms it. Obviously, this way of conceptualizing the evolution of thinking is closely related to the work of Jean Piaget, with whom I worked for several years (see for example Piaget 1971 and Piaget and Garcia 1989). But in contrast to the scientific aims of genetic epistemology, with Piaget as its leading exponent, we are not trying to lay bare a kind of universal latent structure, a set of relationships of which the subject is not aware. Rather, we simply aim at reconstructing the ideas of the creative person in a way that he would probably recognize and appreciate as a reasonable interpretation. However, and this justifies our choice for the term structure, the individual's ideas make up an intricate and dense network, in which every idea is implicated in innumerable others.

Though addressing the long-term development of thought, our work is mainly concerned with high achieving adult individuals and thus differs in a further respect from Piagetian and post-Piagetian developmental psychology. This is one of the main points to be elaborated in *Tracking the Ordinary Course of Development.* Most theories of developmental psychology are unilinear. In their attempt to determine the stages or at least the main developmental landmarks that constitute ontogenesis, they aim to trace the unique developmental pathway that individuals *generally* follow.

But when we turn to the development of creative thought, the picture necessarily gets more diverse. Nevertheless, the concept of a unilinear developmental trajectory continues to frame prevailing psychological research on creativity in significant respects. For example, models that take giftedness as a prerequisite for highly creative achievement, thus trying to predict or explain creative outcomes by gifts, are often committed to maintaining a standard course for a creative life: precocity in childhood, early commitment and achievement, single-minded pursuit of creative goals, and maybe late decline. The relation between giftedness and creativity is addressed in *Coping With the Extraordinary.* In the papers included in that section, we outline an approach to studying the relation of giftedness and creativity that begins from a different perspective. Instead of focusing on giftedness from its beginnings, we pursue a research strategy that takes unique adult performance as its starting point and works backward towards the processes and conditions that gave rise to it. It is the transformation of the gift into creative achievement, seen from its endpoint—adult performance— that we are concerned with: This means that we examine *how* the creator shaped himself to convert promising aptitudes into outstanding accomplishments.

From this angle, it becomes clear that the stereotype of the life course of the creative person misconstrues the developmental peculiarities that creative work necessitates: Outstanding adult achievement does not often follow from the early appearance of cognitive abilities or from unusually rapid development. Rather it is associated with a deviation from the norm, one that might facilitate looking at matters in a new way and construing a point of view of one‘s own. Still, seeing things differently alone does not make up the creator. He also has to see himself as special and as capable of making significant contribution to his field. Such a concept of the self as an extraordinary person is not to be confused with hybris. The person striving for the extraordinary knows her own mission, and mobilizes her entire force to fulfil it. Moreover, she does not pursue it blindly: High goals are weighed up against personal and other resources and energies. Thus, the self-concept of the person sustaining creative work can be thought of as based on a *sense of direction*, enabling the individual to regulate the course of his own progress. That is what "self-construction of the extraordinary" amounts to: Creative development is no quasi-embryological unfolding of god-given gifts, but represents a goal-directed process that is shaped by the individual.

## CREATIVITY AND MORALITY

We were brought up with certain ideas about beliefs and behavior. Not least among them is the idea that morality counts for something, that one's behavior makes a difference, that one's choice of occupation and preoccupation has some effect on the future of the world, or at least on one's own family and loved ones.

And then we get our training as scientists and social scientists. In one myth we learn that valid science is value free, so it's morally good enough to keep your nose clean and your powder dry. We learn to husband our moral resources by deferring our deontic activities to future years, when we are less dependent on the academic establishment. The last two sections of the book, *Creativity in the Moral Domain* and

*Peace and Further Conditions for Human Welfare,* document some of my attempts to reconcile my scientific work with a further strand of activity, i.e. with an enterprise that has different social-political roots than the others: a concern for world peace.

After the American withdrawal from Vietnam, the peace movement ran out of steam. In my own case, I looked for other ways of continuing to express my social concerns. In effect, I re-invented a well-worn idea whose watchword is "creativity and morality." For the most part researchers interested in morality had followed Piaget's lead concentrating their work on the moral judgments of children and adolescents. I was more interested in adults and in action.

Years earlier, very late in the *American Psychological Association*'s convention planning process for 1962, I had submitted a proposal for an anti-nuclear weapons symposium to be held in New York City that summer, under the auspices of the *American Psychological Association* and SPSSI—the *Society for the Psychological Study of Social Issues*. The reply came back from the prominent social psychologist Hal Proshansky: deadline past—too late. Then, a few weeks later, he recontacted me. The organizing committee had just realized that the SPSSI program had nothing on the subject of war and peace. Would I please go ahead as proposed?

The symposium was a great success. Hundreds attended and an account appeared on the front page of *The New York Times*. My opening remarks as chairman were reported in extenso and became the basis for my chapter in a book, *Breakthrough to Peace*, edited by the author and Trappist monk, Thomas Merton.

This encouraged me to go further: In addition to helping to organize local events, in 1968, together with the ethologist Ethel Tobach, I was one of the organizers and first national chair of *Psychologists for Social Action*. Whatever direct value these activities may have had, we were also demonstrating anew to our colleagues that it is possible to be both a social activist and a regular scientist and scholar. I became deeply immersed in organizing *Psychologists for Social Action*—in 1968 my hotel room in San Francisco became its headquarters. At the same time I was giving an invited address to APA's Division for the History of Psychology on the development of Charles Darwin's thinking.

After that APA meeting I found myself caught in a painful trap. I had three major projects going: on Darwin's thinking, chair of *Psychologists for Social Action*, and a study of anti-Vietnam war resisters. It was too much for me, I had to drop something. After much soul-searching, I abandoned the war resisters. I planned to resume that work later on, but I never did, except for a few talks in local settings.

Whenever I recall that decision, I feel regret and a little shame. Still, if I found myself in a similar dilemma tomorrow, I imagine I might make a similar choice: keep some, drop some, try to maintain a balance.

My hope has long been to be effective in both the cognitive and the moral arenas. But I did not set out with any preconceived ideas about integrating the two. When I joined the *American Psychological Association* in 1950, just after getting my Ph.D. at Cornell University, I described my professional interests as "perception, thinking, group processes"—the first describing my then-current passion and my dissertation;

the second naming my intended move into a new field of research; and the third a sort of private code word for a vague conviction that I ought, as a good citizen, some day do something good, both for psychology and for society. By 1966, the list of my interests had mutated to "perception, thinking, and history of science."

While I had thus been mutating in my purposes, my profession had been doing likewise. Specialized division upon division had been added to the rolls. During my half-century of membership in APA, the number of its divisions has nearly tripled. The process of institutional fission seems to be well-nigh ceaseless, perhaps varying in rate from discipline to discipline and from country to country. It may be that this is creative in a fashion not unlike the branching of the *networks of enterprise* of individual scientists. Institutional fission may be vital to ensure the constant rejuvenation of social vision, creating ways to incorporate not only those already powerful but also those struggling.

## EXPERIMENTAL, SOCIAL, AND HISTORICAL TRUTHS

It was 1942 or 1943, social psychology had not yet displayed the bewildering transmutations that ordinary college students can undergo and testimony of the severity of life and death in the Nazi concentration camps had not been given wide circulation. In short, it was possible for an honest academic to believe that, when pushed to the limit, ordinary people would behave decently.

At that time Solomon Asch, the distinguished social psychologist, was my teacher at Brooklyn College, where I was to earn my first degree. He believed and wanted to believe in the ineradicable decency and honesty of ordinary people. He created the first rigged jury experiments in which a bona fide subject was confronted with a panel of peers. These jury members had been carefully coached to lie about something petty and the subject would find him or herself in disagreement with the majority. The judgments to be made were about a banal matter—the relative lengths of lines in a situation where ordinarily every one would agree (Asch 1956). But what was really at stake was the presumption of the reliability of the perceptual judgments of ordinary people. Asch believed and wanted to believe that people would not, in these circumstances, yield to group pressures.

And that is how the first results came out, as I learned in a joyful conversation with one of my fellow students (I was in military training by that time). Asch's optimism and the decency of ordinary people were vindicated.

Then we began to see the whole story. In time there were four major findings that undermined Asch's optimism—three experimental results and one vast array of historical fact.

- The Zimbardo experiment which showed that ordinary university students could be made to take on the brutal attitudes and behavior of professional prison guards, without intensive or prolonged training or any previous experience of hostility between guards and prisoners (Zimbardo 1972).

- Milgram's experiments in which ordinary university students were persuaded to administer electric shocks to other students, including shocks they believed were dangerously close to lethal (Milgram 1974).
- Asch's own continuing experiments which showed that ordinary university students could be persuaded to accept and propagate judgments that were patently untrue (about the length of lines). Only about one fifth of subjects remained completely independent of group pressure, a much smaller number than had been anticipated by Asch.

Then, the full truth emerged of how ordinary people could be brutalized to perform unspeakable acts under National Socialism before and during World War II.

The matter was laid more or less to rest for that moment in the history of science, yet Asch's initial results remained as a bone in my throat. Various escape clauses were considered, but Asch and his cohort—including me—had to change or withdraw from this issue.

In the main, my colleagues and I took truth-seeking and truth-telling for granted. Now we came to see that truth had to be striven for, constructed and nourished.[1]

It was not until I got my second teaching post at the *New School for Social Research*, that I conceived of the Shadow Box experiment. The issue was no longer whether people yielded or not, the issue became how people go about cooperating with each other in deciphering a situation where they are seeing the same thing but from different vantage points—i.e. the two viewing stations of the Shadow Box.

It is of some interest that the Shadow Box experiments were first conceived of in a quasi-political sense. Only later did it become apparent that the question of point of view pervades all situations of judgment from the purely perceptual to the preeminently social.

Thus, for me, the universe of psychological and scientific discourse shifted irrevocably to one which must accommodate experimental, social and historical truths.

HOWARD GRUBER

1. This perspective is well expressed in the title of one of Donald Campbell's papers: "Asch's moral epistemology for socially shared knowledge" (Campbell 1990).

# CHAPTER 1

# THE CREATIVE PERSON AS A WHOLE

## *The Evolving Systems Approach to the Study of Creative Work*

The *evolving systems approach* grew out of my case study of Darwin. In one sense it was a byproduct of this long-term effort but it also provided the key to answering the questions which initiated the Darwin project: how long does complex thinking take and how does it develop?

The Darwin case study began with little more than the aim of tracing the thinking of a creative person over a long period of time. This in itself, however, provided a fresh perspective on the study of creativity, aiming less at its remote antecedents in the creator's infancy, childhood, or biological equipment, and focusing instead on the person's cognitive structures and their changes over time. Thus, the primary underlying question of the approach is *how rather than why* creative achievements emerge. The first paper in this section highlights this point.

This focus of the *evolving systems approach* imposes demands upon the psychologist that cannot be met by the conventional tools of psychology. Examining the belief-systems of someone else, their growth and transformation, requires familiarity with that person's field of activity—in Darwin's case biology and geology. Such a demand cannot always be met. I had already run up against this problem. Before selecting Darwin for study, I had been considering a case study of Faraday, whose voluminous notebooks provide excellent source material. But I gave up this plan because I felt that my knowledge of physics and chemistry was insufficient for the task.

A key methodological idea that distinguishes the case study is that each creative person is *unique*. This runs counter to the way psychologists are trained to think about the individual. Psychometric measurement of creativity assigns subjects to positions on one or more trait dimensions. These positions, however, do not represent actual analyses of a creative case, they are simply deviations from means—individuality is thus explicated as a set of interindividual differences. Experimental psychologists, on the other hand, have learned to disregard individual differences altogether in favor of general trends, but if individual differences are too great, the mean can become meaningless. This bothered me. My earliest empirical work in psychology included experiments in space orientation, which I pursued as an undergraduate in collaboration with Dorothy Dinnerstein. The widely differing subjects' reactions were irritating. But I became interested in such phenomena, even studying the Rorschach test to equip myself to examine the relationship between personality characteristics and individual differences in cognitive processes. During my doctoral research, however, I dropped this theme; it emerged in a new form in my case study on Darwin.

The case study takes the individual as unique. This very uniqueness cannot be fully grasped psychometrically or experimentally. Creative individuals are unique, not only in their oeuvres or in features they share with no one else, but in the way they represent an integration of all aspects relevant to understanding the creative process including personality characteristics as well as the social context. The *evolving systems approach* is holistic in its attempt to understand this organization of multiple components and subsystems, and the case study method provides the means to meet this goal. While the experiment is confined to analyzing small elements of such a configuration, a case study can bring to light the interplay between elements in the system. Here one can examine what functional role single components play within the whole and how they contribute to its conservation and regulation. The idea of uniqueness makes clear that the *evolving systems approach* and the case-study method are closely related, but not synonymous. For example, they may be like those reversible images where foreground and background alternate. The case study throws into relief the phenomena that form the primary concern of the *evolving systems approach*. By the same token, the key assumptions of the *evolving systems approach* justify the application of the case study method.

Though not in principle ruling out generalizations—as we emphasize in *The Case Study Method and Evolving Systems Approach for Understanding Unique Creative People at Work*—the *evolving systems approach* does not fit the traditional picture of a theory as a set of universal laws. I like to say that it is a "weak theory" in the constructive sense, since it does not produce the possibility of making predictions. Rather, it provides concepts that can be used as tools for the analysis of single cases.

The development of creative thinking and the organization it demands along an extensive temporal horizon form the center of the approach. It takes a long time to climb Mount Olympus. The individual creator divides the path into meaningful phases and develops strategies to deal with interruptions. This was a discovery that gave rise to the idea of the *network of enterprise*. The *network of enterprise* is both a finding and a method for depicting the development of creative thought and its products over time. It is a central construct within the *evolving systems approach*, one that demonstrates the purposeful nature of creative work, and contradicts inspirationist accounts of the creative process. Creativity cannot be reduced to a few divine enlightenments, but means work—long-term activity aiming at the production of goods and services. It is incorrect to consider this type of activity as an entirely solitary undertaking pursued by a single individual. Creative work is collaborative to a significant extent. This social dimension of creative work can take many forms: as mentorship, as a loose exchange of ideas, or as close cooperation within a shared point of view.

What is true of productive activity in general applies to the *evolving systems approach* as well: The formulation of our approach to the study of creative work is not the product of a single person, but developed out of the collective effort of my colleagues and students.

Heraclitus taught us that we can never step into the same river twice because the flowing water continually changes. The *evolving systems approach* goes further; it shows us not only that the creator keeps changing but the system within which he or she works—personal, professional, social, political—continues to evolve. The researcher does not remain the same either. Therefore there is no possibility of standardizing meaningful measures of creativity. This prospect of continuous flux frees us to focus on the unique individual.

# The Case Study Method and Evolving Systems Approach for Understanding Unique Creative People at Work

*Together with Doris B. Wallace*

## Introduction

In the evolving systems approach to the case study method, there are three guiding ideas: The creative person is unique, developmental change is multidirectional, and the creative person is an evolving system. The necessary uniqueness of the creative person argues against efforts to reduce psychological description to a fixed set of dimensions. The creative person is not conveniently "far out" along some well-charted path: She or he is unique in unexpected ways. Indeed, it may never be possible to make more than a few obvious generalizations about ways in which all creative people are alike.

The prevailing image of psychological change in developmental theory unfortunately is one of unilinear, cumulative, predictable, and irreversible growth in accordance with a species-general standard sequence. For those using the evolving systems approach, however, development is not restricted to a unilinear pathway since an evolving system does not operate as a linear sequence of cause-effect relationships but displays, at every point in its history, multicausal and reciprocally interactive relationships both among the internal elements of the system and between the organism and its external milieu. Whether change is cumulative and whether it is structurally developmental or not must be worked out in each instance by the investigators.

Thus, the evolving system of the creative person is multicausal and unpredictable—that is, unique. It is unpredictable in the sense that one cannot know exactly what will be the next work that an artist will create, nor can one forecast the next revolutionary theory in art or science. Predictability may be a false god. Nontrivial novelty cannot be predicted. Biologists could never have known how to predict the evolution of the camel, but once faced with the camel and informed about its systematic place in an evolving biosphere, they could hope to understand its evolutionary significance. With well educated hindsight, we may be able to understand the various solutions that come about in response to some eco-pressure for change. With enough foresight, we may also be able to make contingent "predictions" such as:

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> A certain organism will become extinct unless it migrates to a cooler climate;
> or
> Unless a radical creative approach is found for dealing with automotive pollution, industrial societies will asphyxiate themselves.

In the study of creativity, as an alternative to the methodological battle cry of prediction and control, we propose a two-part approach: detailed analytic and sometimes narrative description of each case and efforts to understand each case as a unique functioning system.

Methodological issues are never purely and simply methodological. Overtly or not, they always call into play deeply held convictions about the nature of knowledge and truth. Just as form and content are inseparable, epistemic passions lurk everywhere. Nevertheless, it is our task to disentangle these issues where we can. There are various useful strategies for organizing the investigation of a creative case. The main path we follow in this essay is intended to show some lines an investigator might actually pursue. It should be said, however, that we are not looking for some magic that makes creativity happen, we do not search for the origins of creativity nor for a single model of the creative personality. On the contrary, we ask how creative work works. What do people do when they are being creative? How does the creative person deploy available resources to do what has never been done before?

What is a creative case? What do we mean by creative work? Like most definitions of creativity, ours includes novelty and value: The creative product must be new and must be given value according to some external criteria. But we add a third criterion—purpose: creative products are the result of purposeful behavior; and a fourth, duration. Creative people take on hard projects lasting a long time. (Indeed, their aspirations and purposes often outlive them.) Creative work is a long undertaking to be reckoned in months, years, or decades. Beethoven once made the following statement:

> I carry my thoughts about with me for a long time, often for a very long time before writing them down. I can ... be sure that ... I shall not forget [a theme] even years later. I change many things, discard others and try again and again until I am satisfied; then, in my head, I begin to elaborate the work ... the underlying idea never deserts me. It rises, it grows. I hear and see the image in front of me from every angle (Hamburger 1952, 194).

The criterion of duration gives special meaning to the criterion of purpose, extending creative work over time and capturing the notion of a creative life. To live a creative life is one of the intentions of the creative person.

Implicit in our criteria of purpose and duration—each of which assumes that creative work is inherently a temporal process—is the idea of difficulty. If a particular creative work was easy and obvious, we would not think of it as especially creative since many would be doing it. If there were no constraints, novelty might not be so difficult to produce. Part of the difficulty of achieving a creative outcome arises from the need to make it compatible with human purposes and with the society and culture in which the work takes place. The creative person may well start with a wild idea. Soon it becomes familiar and, within a private universe, no longer wild. But to be effective the creator must be in touch with the norms and beliefs of some others so that the product will be one that they can accommodate and relish. Even the person who is far ahead of the times must have some community, however limited, with which to engage and connect. For example, during his most secretive years, Darwin isolated himself from the scientific community, but only with regard to the work he was doing on evolutionary theory. In other respects he was, in that period of his life, well ensconced in the world of science, holding office in professional societies, giving papers at meetings, and collaborating with various experts in different branches of biology (see Gruber 1981e).

Einstein provides another example. During the years when he was working out the special theory of relativity he met regularly in an informal group of three men who dubbed themselves the "Olympia Academy." They usually met in Einstein's apartment and discussed everything under the sun—and probably the sun itself—but especially Einstein's theories.

Of more recent vintage is the story that the physicist-mathematician Freeman Dyson relates. When he saw that the physics community, including its most brilliant members, could not understand Richard Feynman's unorthodox methods for solving problems in quantum electrodynamics, he undertook to serve as the bridge: He worked steadily with Feynman for a year, until he had mastered Feynman's diagrammatic visual approach and could transmit it to others of more algebraic bent (Dyson 1979; Schweber 1994).

When the gap between the creator and others is too great, two primary strategies are possible: to modify the work to make it more acceptable, or to educate the potential audience to greater acceptance. Both of these strategies show the others the way from the present to the future.

## HISTORY, THEORY, AND METHOD

To see where our methodological approach is situated in the spectrum of possible approaches, a brief survey is in order. One exclusion should be mentioned, works known as *psychobiography*. We have omitted this area because it deals primarily with the personality and social relations of the person. We intend this remark not as a criticism, but as a logical consequence of our commitment to the study of the creative process, to the study of the creative person at work. In some of our writing we have referred to our work as "cognitive case studies," not to exclude aesthetic, affective, and moral issues but to avoid the appearance of taking on the tasks of the psychobiographer.

The year 1950 is often hailed as the moment of rejuvenation of creativity research after psychology's long sojourn in the desert of behaviorism. That was the year of Guilford's presidential address to the American Psychological Association (1950), in which he advanced the goal of psychometric and factoranalytical approaches to the abilities and other characteristics of the creative person. The factors were to be discovered by the construction of tests of creativity that could be administered to large enough samples to make factor analysis possible. Thus, Guilford's approach was centered on component abilities, and correlational studies of them, in which it was assumed that the more the subject had of a certain ability the more it contributed to that person's overall creativity. The main ability that was distilled out of a vast research effort was "divergent thinking." Without going far into this subject three things can at least be said. First, decades later, there is remarkably little evidence concerning divergent thinking in highly creative people (Barron and Harrington 1981). Second, it is not self-evident how the ability to produce many ideas is related to the ability to produce a few superb ones. Third, the question remains open: Just how does the creative person at work go about making use of the ability to produce ideas? (For further discussion see Ochse (1990) and Weisberg (1993).)

The difference between our approach and factor analysis is that our "factors" are derived from the doings and sayings of actual creators. Can a description be both analytic and holistic? Yes, as in Wertheimer's formulation of the laws of perceptual organization, such as proximity, similarity, and common fate. For a description to be holistic without being vacuous it must make use of some tools of analysis.

Five years before Guilford's presidential address, Max Wertheimer, one of the founders of Gestalt psychology, brought out his book, long in the making, *Productive Thinking* (Wertheimer 1945). This work dealt with seven cases, each at chapter length. Three of the cases—Gauss, Galileo, Einstein—were creative thinkers of the highest order. Wertheimer's treatment of problem solving emphasizes its analogy with perception, using structural concepts such as transformation, recentering, gap-filling, and figure-ground reversal. Non-Gestaltists borrowing from the theory often put the emphasis on sudden insight, the so-called "Gestalt switch." As a characterization of Gestalttheorie this is a little misleading. For example, Wertheimer's treatment of Einstein (whom he knew and interviewed) described ten phases in a nine-year process eventuating in the special theory of relativity plus many questions left unanswered. Wertheimer's approach emphasizing structural transformations spread out over time resembles our constructionist approach. Miller (1984) gives a fuller and more historical account which is, nevertheless, in tune with major aspects of Gestalt theory.

In spite of their profound differences, Guilford and Wertheimer have one thing in common, a preoccupation with problem solving. There was an earlier tradition, represented by Titchener's *Lectures on the Experimental Psychology of the Thought Processes* (1909), in which the emphasis was on the experiential aspects of thinking, such as visual imagery or feelings of a problem-state. With the rise of behaviorism, such experiential, phenomenological studies went out of favor. In more recent years there has been an upsurge of interest in inner experience as such, with special emphasis on visual imagery. However, there is not yet a solid body of knowledge about the role of such processes in creative work. From all this it can be seen that there is a close relation between theory and method in the study of creativity. Indeed, it might almost be said that the method is the theory in the sense that it specifies what is considered important and worthy of study.

Each major theoretical approach has its own methodological commitments and attitudes toward measurement. In the factorial approach, measurement is the key requirement. The guideline is that everything that exists in some quantity and can therefore be measured. But the actual position taken is even stronger: Everything important should be measured.

In the Gestalt approach, measurement hardly appears. The key concern is to understand the structure of the situation that the subject confronts, and to understand how the creator transforms the situation by a series of moves analogous to perceptual phenomena, as mentioned above. In spite of the Gestaltists' emphasis on structure, they are not usually grouped with the "structuralists." The latter are concerned with structures exhibited in varying situations, as though they were carried from one to another in the mind of the thinking subject, thus providing trans-situational norms. The Gestaltists, on the other hand, emphasize structures to be found within situations, to be found by getting inside rather than standing outside and above, moving "straight from the heart of the thinker to the heart of his object, of his problem" (Wertheimer 1945, 236).

The structuralists—who might also be called constructionists, epigeneticists, or developmentalists—are closely related to the Gestaltists, with one major difference noted just above. Indeed, Piaget liked to say that he had almost become a Gestaltist, before he discovered the problems of development. Perhaps it could be said that Wertheimer tended to go more deeply into fewer tasks or problems, while the structuralists, more concerned with discovering universal norms, necessarily had to look at many problems of a given class (i.e., dealing with space, time, causality, chance, etc.). Of course, the major difference is that Piaget was deeply concerned with the problem of development, whereas the Gestaltists, with their root metaphor founded in the perceptual situation of the moment, tended to ignore problems of development.

Methodologically, the most striking characteristic of Piaget's work is his use of the "clinical method." This means, in the first place, deeply probing interviews centered around some cognitive task selected by the investigator. The child is asked to solve some problem and is both observed and queried as to his thought processes while he or she does it. This much is not so different from other investigators of problem solving, except that there is less interest in finding "the" solution and more in probing for process. This is well expressed in the title of Ginsburg's book: *Entering the Child's Mind: The Clinical Interview in Psychological Research and Practice* (1997).

But there is another characteristic of the clinical method that goes beyond the single interview. Typically, in Piaget's realm, a group of investigators is working on a set of ten to twenty related problems or experiments. This is necessary for the structuralist approach, since the aim is not so much to find out how the child solves this or that problem, but to understand the epistemic structure that regulates a whole class of tasks, for that is the structure developing. We consider this work to be germane to our work on creative thinking; indeed some people would argue that the child discovering some concept, like conservation of matter under transformations of shape, is being just as creative as Archimedes when he took his famous bath. Piaget himself said now and then that childhood is the most creative time of life.

What distinguishes Piaget's version of developmentalism from our use of the case study method to elaborate the evolving systems approach is our interest in the *individual*. Piaget would argue that his goal was to get beyond the psychological individual in order to attain the "epistemic subject" or the set of regulatory norms that any knowing system must develop. In an interview in 1975 Piaget put it this way:

> Generally speaking—and I'm ashamed to say it—I'm not really interested in individuals, in the individual. I'm interested in what is general in the development of intelligence and knowledge, whereas psychoanalysis is essentially an analysis of individual situations, individual problems ..." (Bringuier 1980, 86).

This lack of interest in the individual showed itself throughout his work, not least in the simple fact that each child who participated in the Piagetian experiments did so only once. There was no effort to characterize enduring characteristics or concerns of the individual or to map out the developmental pathway actually taken by an individual. And this, of course, is exactly the focus and preoccupation leading to our use of the case study method and the evolving systems approach.

Our interest in the creative process requires that we look searchingly at each case we take up. Whereas Piaget and similar structuralists may have neglected the wider context in which the person develops, we have found it necessary and fascinating to pay careful attention to it—but without losing sight of our central concern with the question: How does each creative person do it? And it must be added that one set of contexts for our work has been all that we could learn from other approaches to creativity. An excellent contribution exhibiting this kind of prolonged attention to the creative individual—prolonged over years, so that one can see and grasp the developmental pathways taken, is the work of Franklin on seven women artists (Franklin 1994). As against the notion of a single set of stages to which all developmental processes must conform, Franklin found "three modes of change: generative problem solving, focused exploration and converging streams" (p.172). The point here is not to commit oneself to a new orthodoxy hailing just these three types of developmental pathway, rather, the point is to encourage a wider search for varieties of pathways, and to take note of the heterogeneity to be found even within a group of women artists who have much in common with each other.

Similar in their theoretical intent and methodological approach are Gruber's work on Darwin (1981e), Wallace and Gruber's collection of twelve cognitive case studies (1989), a further collection published as a special issue of the *Journal of Adult Development* (see Gruber 1996b), and a special issue of the Creativity Research Journal constituting a collection of ten studies of scientists (see Miller (1996a) for details).

This volume is also a good starting point for tracking Holmes' fine studies of Bernard, Lavoisier, and Krebs. Of particular interest is a special issue of the *Creativity Research Journal* carrying autobiographical accounts of five Nobel laureates and some others, all in the biomedical field (see O'Reilly and Holmes (1994) for details). As one of the participants in the symposium on which these accounts are based, Gruber has the impression that the process of discovery in the biomedical field is quite different from that in the physical sciences.

In general, the studies listed mentioned above share the common feature of giving a modicum of background information and then focusing intensely on the detailed structure of the individual creative process as exhibited in each study. A *Passion for Science*, a collection produced by Wolpert and Richards (1988), demonstrates effectively that it is possible to maintain the same developmental-process perspective in relatively brief studies. There is a steady accumulation of biographies and a few autobiographies of scientists, many of which do maintain a balance between the purely personal and cognitive-creative issues. Of these we cite only one, in part because its title alone says so much that is relevant to our project: *A Feeling for the Organism: The Life and Work of Barbara McClintock* (Keller 1983). Taking our "organism" to be the creative person at work it does seem that we are moving toward capturing the feeling.

## N=1 OR N=MANY?

For the most part the rubric case study method has been used to refer to studies in which there is one central figure, N = 1. This has had two purposes. First, to make the task more feasible. If the study is to be about the creator's work, it seems obviously easier to know one creator and describe his or her work thoroughly than to grapple with many. Second, we are frankly interested in celebrating individuals and the idea of individuality, rescuing them from the conceptual pigeon-holes of "species specific behavior," the "bell curve," and the "epistemic subject." As we show below, we believe this respect for the individual can be achieved without losing sight of the many ways in which creators are embedded in their social contexts. Indeed, it behooves the investigator of the single case to search assiduously for the right movement between these two poles. The decision to do so is not itself a solution to the problem, it is only a methodological proposal. There will be at least as many solutions as there are cases.

The central point is not really the size of N but rather the shaping of the case study so that it maintains a primary focus on the creative work. Moreover, the investigator must choose the case or cases with some sense of his or her own intellectual assets, in other words, some confidence of an adequate level of understanding the work itself.

In some instances, of course, dealing with more than one case at a time becomes essential for understanding the work. The Curies, the Wright brothers, Marx and Engels, the Marx Brothers, Inhelder and Piaget, Braque and Picasso, Gilbert and Sullivan—all are examples of close collaborations. Then there are cases of convergence of efforts initially independent, such as the work of Feynman, Dyson, Schwinger and Tomonaga mentioned above, this case has aspects both of collaboration (Feynman and Dyson) and of convergence of independent streams (Feynman, Schwinger, and Tomonaga).

Gardner's work (1993) represents yet another rationale for multiple case studies. He selected seven individuals using two main criteria: First, there was to be one from each of the seven types of "intelligence" he had singled out earlier (Gardner 1983); second, all of the individuals lived within a relatively narrow historical period—their collective life-span runs from 1856 (Freud the earliest born) to 1973 (Picasso the last to die). The others are Einstein, Stravinsky, Eliot, Graham, and Gandhi. These seven did not know each other, did not work together. But, Gardner argues, they can be taken as makers of the modern era. Of course, Gardner does not go into the details of their actual creative work at the same level as might be expected of a scholar choosing a narrower range of subjects. Nevertheless, he achieves a decent balance between concern for the work itself, for its historical context, and for the creative person doing it. For a more detailed examination of this work see Gruber (1996a).

## CASE AS SYSTEM: PERSON AND MILIEU

Csikszentmihalyi has criticized Gruber for focusing attention on the evolving person while neglecting its ever-present and inseparable partner, the evolving milieu (Csikszentmihalyi 1988b; Gruber 1988c). There is some justice in this criticism, at least so far as it pertains to the 1988 article. But in Gruber's key work, *Darwin on Man: A Psychological Study of Scientific Creativity* (1981e), that requirement has been rather fully met by an institutional approach. In the section on "the intellectual setting," there is a chapter on general ideologica1 conditions prevailing in Darwin's world, a chapter on the role of the family in shaping his Weltanschauung, and a chapter on Darwin's teachers. There is also a chapter on the relationships between public and private knowledge, so important in Darwin's case and in other cases where dangerous ideas are at stake. This public-private relationship is expanded in an appendix added to the 1981 edition, which was omitted from the original work (Gruber 1974) and which is further expanded in a later publication (Gruber 1994b). The latter also goes more deeply into the relation between Darwin and Wallace, especially with regard to the issue of public and private knowledge.

There is, then, more than one way to treat the person as a system within systems. The tripartite division—field, domain, person—that permeates the work of Feldman, Csikszentmihalyi, and Gardner (Csikszentmihalyi 1994), is a very useful approach. Gruber's approach has been to situate the individual within a set of milieux that corresponds to the institutional framework within which the person develops. To be sure, no list of institutions is as yet cast in stainless steel. Nevertheless, the institutional approach has the merit that, for the most part, institutions are relatively easy to define and identify: family, school, work-place, and community make a good beginning.

Then there are subtler and sometimes more transitory institutions, like the European students' *Wanderjahr* and the "invisible colleges" that are described by some sociologists of science.

This approach is amplified below under the heading of "contextual frames." For the moment, the point we wish to stress is that there are various ways of parceling out a creative life into the societal arrangements within which it unfolds. Karl Marx may be out of fashion now, but not so long ago a discussion of this subject, creativity and society, would probably include some reference to social class. In the Darwin case, social class seems particularly relevant (see for example Moore 1985); in Einstein's case, not. Or, as Marx's collaborator Friedrich Engels wrote of "social history":

> Anyone therefore who sets out in this field to hunt down final and ultimate truths, truths which are pure or absolutely immutable, will bring home but little, apart from platitudes and commonplaces of the sorriest kind ... (Engels 1894, 104).

Of course, one person's platitudes are another's beatitudes, so Engels' admonition may not be always germane. Still, the key point remains: The student of the creative case must not use the task of examining context as substituting for the task of penetrating the case in all its inwardness.

## SCALE

There is yet another distinction to observe in shaping a case study—the issue of scale. Some case studies focus on the single opus, as in Arnheim's (1962) work on Picasso's *Guernica*. This choice of focus probably requires both the deepest technical knowledge and the greatest empathy, for the investigator must understand the creator's moves down to the last brush stroke. At the other extreme is a broad focus on the œuvre which requires that the investigator perceive the broad movements of the creator's thinking, intuit his or her *Weltanschauung* understanding the life task that animates the œuvre. This distinction between opus and œuvre has hardly been noticed, much less used as a guide in shaping case studies. Tentatively we recommend that each investigator at least try out several such foci as part of the process of choosing the most fruitful orientation for a particular study.

## MULTIPLE FACETS

Creative work is always a many-faceted undertaking. Whether a given facet is a description to be attributed to the creator or to the investigator may vary. But we bear in mind the need for a certain humility: Any facet of which we may become aware owes its origin to something the creator said or did, and was therefore something of which the creator was most probably aware as well.

It will be seen that facets sometimes lie within other facets. Since any further hierarchical organization of the system may be quite labile, we simply number the facets successively as they occur in this account. Any description of these facets is bound to be incomplete, and every case study must involve careful choices of the facets to be dwelt on. These choices will take into account the scientific aims of the investigator, the particulars of the case, and the availability of material for study. The facets we take up here are quite similar to the ones we suggest to our students. Experience has shaped our plan and shows that it is a workable guide for the study of a wide assortment of creative cases.

Treating the study of the creative case as comprising a large number of distinct facets does risk losing sight of the individual as a whole person. That would resemble the surgeon's verdict: "The operation was a success but the patient died." Our approach, however, is holistic in several senses. First, in our treatment of each facet, we aim at completeness. For example, in dealing with the creator's purposes we use the network of enterprise as a way of considering all of his or her enterprises. Second, we try to deal with several main facets together, in their interaction—for it is in these interactions that we recapture the whole-quality of the creator. Third, our conception of the creative person at work as comprising three great sub-systems—knowledge, purpose, and affect—obligates the investigator to deal with the way they come together in the person as a whole. The concept of loose coupling contributes to this holism: The components are joined together but not in the same way for any two cases. We must therefore study them in their particulars and in their concrete detail to understand how this creator differs from that one. Fourth, our own interest in development and our insistence on the idea that creative work is extended in time requires that the investigator examine the case at more than one moment in time (i.e., case time). This in turn leads to the construction of narrative as a natural component of any case study.

The level of analysis we aim at resembles the physiologist's. First, study some organ or organs of the body, then study how that organ contributes to and is affected by its manifold connections with other organs— i.e., the system as a whole.

As we move along in this discussion we will encounter certain facets, each of which is large enough to deserve at least a whole chapter, something akin to organ systems such as the central nervous system, the skeletal system, the endocrine system, and so on. Some of these facets will be dealt with at length, others only mentioned. Some lie comfortably within one or another of the three great sub-systems mentioned earlier—knowledge, purpose and affect. Others cut across them. For example, metaphors are often both cognitive and affective expressions, such as Blake's line, "The tygers of wrath are wiser than the horses of instruction" (Blake 1946).

*Facet 1: Uniqueness*

Murray and Kluckhohn (1950) maintained that every person is like all others in some respects, like some others in some respects, and like no others in some respects, referred to by Wallace as Alpha, Beta, and Gamma respectively (Wallace 1989a). But it is the *distribution* and *configuration* of Alpha, Beta, and Gamma—how they are represented and entangled so-to-speak—that makes up the whole person and the person's individuality and uniqueness, Omega. So when we study the creative person, we are studying aspects of Omega, not merely Gamma (like no others). Most psychometric studies of creativity try to identify attributes that creative people have in common. In terms of the above theoretical framework, their focus is on Beta (like some others). Unfortunately, this blurs important issues. Attributes such as high aspiration level, obsession with work, and good problem-solving skills can be observed not only among world-level creators but among many a corporate person in a gray flannel suit.

*Facet 2: The Epitome*

The narrative in the case study method will include an epitome, a succinct account of what the creator achieved and how this compares with contemporaries working in the same vineyard. The point is not to decide who is "the greatest." Rather, the aim is to understand the obstacles our case faced and how he or she dealt with them. In a more extended account the question will be posed: What led up to and what followed from the work in question? This would at least touch on precursors and descendants of the case. Perhaps even more important would be an account of the general situation in which these historical movements occurred.

*Facet 3: Systems of Belief*

From the narrative that can be constructed of Darwin's evolving system of beliefs during the voyage, a schematization can be drawn. Darwin's belief system evolved through some four or five major stages from 1831 to 1836 (See page 129).

In 1838, Darwin himself constructed a different schematization of his thinking at an early stage in his search for a workable theory of evolution. In the B Notebook, his first notebook on evolution, at the top of page 36 he wrote "I think" followed by the celebrated schematization of the irregularly branching tree of nature evolving (see Figure on page 24).

Darwin's case is among those few where we have a sequential record of his thinking. Fortunately for us, although he did not date every entry, he recorded his ideas and observations in bound notebooks, often numbering the pages himself. This makes it possible to see each of Darwin's tree diagrams in sequence (at least six are known), and to make some sense of what was troubling his thinking, leading to each new version of the diagram. Thus he recorded his thinking in two modalities, verbal and visual graphics. While the Darwin manuscripts are unusually rich, we believe that most creators leave a trail rich enough to tax all our hindsight, wit, and wisdom as we struggle to explore and make sense of it all. The student of the case must be bold enough to interpret the material available.

Darwin worked in an intellectual climate that revered the seemingly definitive, all-inclusive and successful determinism of Newton. This attitude provided a philosophy of science that relied on general laws and an embodiment of scientific knowledge in a form that Darwin hoped to extend from physical to biological science. This intent is expressed in the famous last paragraph of the *Origin of Species*, where Darwin wrote:

> ... There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved (Darwin 1859, 490).

At one level, Darwin was an exponent of this determinism. And yet, at another level he was the chief originator of an alternative approach to nature, both probabilistic and non-determinist. Or, in an alternative formulation suggested by Schweber, Newtonian thought is based on a conservation principle whereas Darwinian thought is based on a principle of maximization—life fills up the available niches and creates new ones unpredictably. Life becomes as complex and perfect as possible (Schweber 1985, 47-55), and each new becoming opens the way to new possibilities (Piaget 1987).

Evidently then, in his historical situation, Darwin was poised between an old and highly successful way of thought and a new way just coming into focus. The reader will no doubt have noticed that the dilemmas Darwin faced in this regard resemble those faced by students of creative thinking who may have been raised in quite deterministic ways of thinking still prevalent in psychology. Thus, students of creative work may profit by being sensitive to what they can learn from their cases. In the case study method the narrative is a jumping-off point for reflective thought. The case study method is not the royal road to the best way of thinking; it is only an approach that may help us to enrich our repertoires for understanding the many ways of creative work.

### *Facet 4: Modalities of Thought*

In discussions of creative work one hardy, perennial group of questions concerns the modality in which the creator thinks. Is all really creative thinking visual? What about musical composition? Did Wordsworth really think in iambic pentameter? Do mathematicians think in equations? If the real work of thinking is unconscious, does it have to take place in some specifiable modality or is there "amodal" thought analogous to Michotte's amodal perception (Michotte, Thinès, and Crabbé 1964)? Did Aristotle really say that metaphor is the essence of real thought? And, urgently, how can this investigator work out this case's modalities of thought?

Since we are delving into the realm of private experience we cannot expect all the questions to be answerable, or all the answers to be firm. But we can at least approach some of the issues. For example, Miller argues that at a certain point in the history of theoretical physics, in 1923, "Bohr's planetary atom was abandoned" and replaced by a model using simple harmonic oscillators (Miller 1996a). "This is a non-visual metaphor because each atomic electron is represented by an infinity of harmonic oscillators" (p.115). What can we learn from this? First, that metaphors have histories. Second, that a transformation can occur from one modality to another (visual to non-visual, in this instance). Third, that metaphors and their transformations are consequential: In this instance, the developments in question led to the formulation of modern quantum mechanics. Finally, that it may take a considerable degree of expert knowledge to penetrate some niches in the tangled bank of the mind. (See Gruber (1996b) for a fuller treatment of the modality question.)

In the study of metaphor there has been a strong tendency to take one or another metaphor and work it to death, using it as the command center of a given creator's thinking. When Gruber did his work on Darwin's use of metaphor, he began with the image of the irregularly branching tree of nature. But he soon discovered that Darwin made use of four or five families of metaphors just to clarify the idea of evolution through natural selection. Moreover, each variant within a family made sense, i.e., had a function in the web of Darwin's argument. A similar argument, made by Osowski (1989), applies to William James' chapter, "The Stream of Thought" in his *Principles of Psychology* (1950).

These findings led us to the concept of an "ensemble of metaphors." This has now become the recommendation that the investigator examine all the metaphors in a given text and try to express how, taken together, they represent a field of meaning. Although this is a useful approach it does lead to one major complication. When the creator is not making a metaphor, what is he or she doing? Associating ideas? Constructing a causal chain? Describing a scene? Re-counting or constructing a narrative? Classifying objects or people or events? Without some such taxonomy it may not be possible to answer the question: Under what circumstances does this creator resort to metaphor (not forgetting that one possible answer is "always")?

Nevertheless, with all its complications the examination of ensembles of metaphor is a promising way to delineate the main lines of a developing thought process. It was put to good use by Osowski in his analysis of the family of metaphors in which James' most famous metaphor, the stream of consciousness, is embedded.

*Facet 5: Multiple Time-Scales*

It would be difficult if not impossible to construct the narrative of a case study using only one time-scale. Short-term activities and experiences are embedded within longer episodes, and so on. Arnheim (1962) gives a penetrating account of one month in Picasso's life, the month in which he created *Guernica*, the mural depicting the horror of the Nazi raid on a holy city in Spain. The mural is widely acclaimed as one of Picasso's most important works. But to understand it and the processes that produced it one needs to look at Spanish political history, at the community of artists in Paris in the 1930s, at Picasso's own development as an artist, and at the moment-by-moment flow of work. These events each have their appropriate time scales, ranging from a few minutes to many decades.

Wallace's study (1989b) of the British novelist, Dorothy Richardson, is an interesting example of the discovery of the interrelating time-scales within which the creator worked. In Richardson's case there were the decades of an actual life as depicted in her autobiographical novel; there was the much longer period in which the writer composed the novel; and there were other time-scales of events in both domains.

*Facet 6: Purposeful Work and Networks of Enterprise*

As we have already emphasized, an overall purpose is central to creative work and is part of the motivation to go on working for long periods or for a lifetime. As this process is set in motion, ideas and projects proliferate and the means for achieving the overall purpose become more numerous and more complex. Organization is needed to order this work, to set subsidiary goals, and to benefit the person's working economy as a whole. The work entails mundane activities or tasks, and it requires identifying and solving problems that arise out of a given project. Thus the course of a single project is hierarchically organized: projects, problems, tasks. But there is another level of the organization of work, *enterprises*. An enterprise is an enduring group of related activities aimed at producing a series of kindred products. An enterprise embraces a number of projects. Most typically, as one project is completed new possibilities come to the fore, to be undertaken next or later. Finishing a project rarely leads to a state of rest; rather it triggers further work, as if completion furnishes the momentum to go on. Thus, each enterprise is self-replenishing. Einstein produced the special theory of relativity in 1905, then took eleven years more for the general theory of relativity, then went on to struggle and search for a unified field theory (see, for example, Pais 1982). In spite of his commitment to a unitary theory, for purposes of analysis—i.e., to understand how he organized his work—we can arrange his works under different categorical headings or enterprises.

To construct a network of enterprise it may be advisable to begin with a simple scheme, such as the dichotomy that Gruber noted in his examination of Darwin's activities during the *Beagle* voyage: Most of Darwin's work during the voyage could

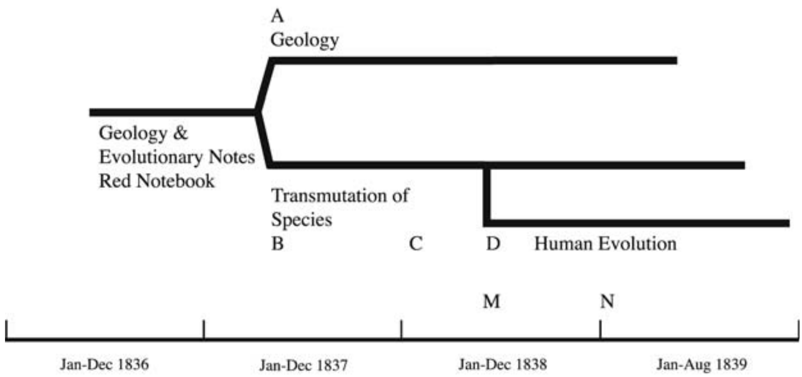


*Figure 1.* Darwin's evolving network of enterprise, 1836-1839. The organization of Darwin's notebooks reveals the main branches of his emerging network of enterprise. Adapted from Herbert (1980).

be classified as either geological or zoological, and the changing outputs of work in these domains was revealing to plot over the five years of the voyage. What it revealed is that Darwin's work in geology far outweighed his zoological work.

But work at the frontier typically reveals other challenges, and the network grows more complex. An early stage in Darwin's development, the "notebook years" immediately following the *Beagle* voyage, can be schematized as a branching structure producing a trichotomy—roughly, geology, general evolutionary theory, human evolution. This trichotomy is embodied in the notebooks Darwin kept during the years 1835-1839. Of course, it is a great simplification, as each notebook contains a wide variety of topics.

In Piaget's case, his sixty books and longer monographs provided the data base and produced a network composed of ten enterprises—each with its own starting date, and with many cross-connections. The ten strands are: natural history, religion, epistemology and synthesis, sociology, logic, ontology, biology, representation, perception, education. Doubtless, when the process for Piaget's whole oeuvre (over 1,000 items) is completed, new categories will emerge, and new connections among them.

With a refined enough eye and enough time for reflection, one can always produce more categories. There are "lumpers" and "splitters" here just as in any taxonomic effort. But our goal is not to discover the one true network of enterprise or taxonomy but to get an overall view of the creative person at work and to discover interesting lines for further study. Sometimes simplification is appropriate. For example, in his late twenties and early thirties van Gogh moved away from his early religious preoccupations and toward full commitment to a life in art. This movement and the vacillations of a long transitional period are well revealed by plotting the occurrences of remarks on these two subjects in his letters to his brother Theo (Wimpenny 1994). Once having established the reciprocal waxing and waning of the two preoccupations of religion and art, further reflection is called for, to examine the sense in which van Gogh remained a deeply spiritual person. So we must learn, and re-learn for each case, how to navigate between simplicity and complexity, and between countable objectivity and sensitive, literate reading of the creator's products.

Some of our colleagues have interpreted the idea of networks of enterprise as meaning the more enterprises, the more creative the person. This parallels and closely resembles the fallacy that high scores on tests of divergent thinking are tokens of great creativity. As Gruber has noted:

> Baldwin, in his 1898 presidential address to the American Psychological Association, *On Selective Thinking*, ridiculed this scattershot image of thought ("scatterbrained" he called it) and spoke of human creativity as the product of purposeful, reflective thought (Gruber 1982f, 4).

*Dynamic Features of the Organization of Purpose.* From the investigator's point of view, the purposes of a network of enterprise are first to provide an overview of the patterns of continuity and relationships among enterprises by showing the course of the work as a whole over years or decades of the working life in a simplified form; and second, to serve as a counterpoint to the detailed and hermeneutic narrative derived from examining texts such as the person's notebooks, critical comments, autobiographical accounts, correspondence, and creative products.

Mapping a network of enterprise is a task performed standing "outside" the case (see "Investigator Roles" below, page 60). It enables one to see the development of the creative person's work enterprises over a lifetime as an aerial map. For example, midway in the *Beagle* voyage Darwin was thinking about the way in which billions of coral organisms made the coral islands of the Pacific. Soon after the voyage he gave two papers, both on the ways in which organismic action re-makes the earth. The first was his paper explaining his theory of the formation of coral reefs (Darwin 1837a). The second was his paper explaining how the action of the digestive systems of billions of earthworms is constantly transforming vegetable matter into topsoil (Darwin 1837b). Without knowing about the coral reef paper, the worm paper would seem to come out of nowhere. Darwin's study of earthworms continued until 1881, the year of his death and also the year of publication of his book about worms (Darwin 1881). This is a pretty example of the pursuit of different enterprises in parallel, i.e., during the same time period—since the worm work was done in parallel with everything else that Darwin did during those forty-five years.

A common pattern in creative work is this simultaneity of enterprises. The creative person is often engaged in more than one enterprise at a time. For example, as noted, during the *Beagle* voyage Darwin wrote copiously on zoology, geology, and other topics. After the voyage, beginning in 1836, the development of Darwin's enterprises is represented in the various notebooks he kept (Gruber 1981e). As is clear in Figure 1., Darwin began the Red Notebook in 1836. This book mostly contains his geological notes, but it also includes some of his earliest notes on evolution. By mid-1837, Darwin began a separate notebook (the A Notebook) entirely devoted to Geology. The very same day he started the B Notebook containing his first notes on the transmutation of species. When the B Notebook was full, Darwin began the C Notebook in which he continued his transmutation notes and began to write about the evolution of mind. When this notebook was full, Darwin continued the transmutation notes in the D Notebook and the same day began the M and N Notebooks, which dealt with aspects of human evolution, such as the expression of emotion in and the continuity between *Homo sapiens* and other animals. Figure 1. shows this branching and simultaneity in Darwin's enterprises. The development of differentiation and specialization is striking and occurred when an enterprise had proliferated to the point where it demanded separate status.

A second feature that a network of enterprise reveals is continuity. By organizing the work into distinct enterprises, it becomes possible to put tasks aside and resume them without always starting from scratch. The paraphernalia of writing, labeling, and filing, and the separate social and professional networks corresponding to the various tasks and projects support this twin need for differentiation and stabilization.

The simultaneity and duration of enterprises (which we have found in cases we and our colleagues have studied) have other advantages. Resuming work on an enterprise after a lapse means that the fruits of work gained from other enterprises can be applied to the work at hand; techniques learned or refined, or knowledge acquired in one enterprise can be put to use in another. Another way of looking at patterns of interrelationships of this kind is to see them as a web of interruption and resumption, such that a task or project undertaken in one enterprise becomes an interruption in another. Seen in this way, the interruption itself eventually moves the creator to resume work in the interrupted enterprise. Interruptions of this kind have well-known dynamic effects in short-term laboratory situations (Lewin 1935). The concept of the network of enterprise permits the application of the same line of thought on the scale of the life history. It evokes a picture of the creative mind as a system, in Newton's words "never at rest" (Westfall 1980, ii).

As described earlier, the network of enterprise is a phenomenon drawn up by the investigator as seen from the latter's point of view. But from the point of view of the creative person, there are other things to be said. At any temporal point in the network, the creative person probably sees the future of his or her work differently—

perhaps less distinctly in the long-term for example—than is depicted in the network drawn over the life by the investigator. But looked at cross-sectionally rather than longitudinally, the network represents, at any time, the creative person's self-conscious understanding of the history, present state and future concept of his or her work.

In addition to the sense in which we say that several enterprises may be active at the same time, there are some enterprises which have gone dormant. The evidence justifying the word *dormant* rather than discontinued is the fact that when the person resumes an interrupted activity he or she does not begin at the beginning but takes cognizance of the work done earlier. Indeed, the creator is likely to have a number of means available to accomplish this purpose, such as notebooks and early studies or drafts, old colleagues who can be looked up when appropriate, and the unfinished work itself. More generally, both the dormant and the active sectors of the network of enterprise contribute toward the creator's maintenance of his or her self-concept, and this is necessary for creative work.

In a fully worked out network of enterprise one would want to consider its relation to the paradigms within which the creator functions. This is a neglected question in several ways. First, we do not know what proportion of a person's work is paradigmatic as against the proportion that is consciously outside and—as in Darwin's case and Piaget's—undermining the paradigm. Second, suppose that two or more creators each worked wholly within the identical set of paradigms. They would not do so in the same sequences or with the same emphases, or, most important, with the same extra-paradigmatic intent regarding the whole. For example, in the post-*Beagle* years Darwin worked in very conventional ways with a number of colleagues expert in diverse domains. At the same time, his work on evolutionary theory was revolutionary and secret. In the long run it may have been less important that it was secret than that it was extra-paradigmatic. Third, it is not clear how the dichotomy, paradigmatic and revolutionary, applies to creative work outside the sciences.

The network of enterprise is a system of goals. One of the important ways in which goals are maintained and managed is by making *initial sketches*. These provisional productions can take many forms, such as project proposals to potential patrons, actual sketches, or even dreams. When Picasso set out to paint *Guernica* he made a small rough sketch of what he was aiming at. In seeming self-contradiction, Picasso said, "the first vision remains almost intact in spite of appearances" but a moment later he said, "A picture is not thought out and settled beforehand. While it is being done it changes as one's thoughts change" (Arnheim 1962, 30). We can understand the conjunction of these two remarks if we think of the initial sketch as having both exploratory and regulatory functions. How the creator manages to balance these different functions must be discerned anew in each case. Most homeostatic systems are negative feedback systems: The controls are set to make corrections that eliminate deviations from some desired value (such as blood temperature = 98.6 F). Creative systems require some positive feedback: When an interesting deviation from a norm occurs, the system responds by noticing, labeling, and amplifying it (Maruyama

1963). This central problem in the study of creative cases—how novelties are seized upon and elaborated—has hardly been identified, much less carefully examined and applied to specific cases.

*Facet 7: Problem Solving*

As discussed above, when the modern impulse to study creativity gathered momentum in the years following World War II, there was a focus on problem solving as the facet of greatest interest. Laboratory studies of problem solving are fascinating in their own right but do not necessarily address the topic in ways that are very revealing for the study of creativity. This led to a rather wide search for other important aspects of the creative process, such as the facets we have taken up in this essay. The pendulum of interest swung away from problem solving. With the case study method, however, the investigator is responsible for taking up what is important to the creator, not only what is fashionable. We believe we are now in a good position to return to problem solving as an important facet of the creative process.

Ochse (1990) and Weisberg (1993) each give good accounts of research in this area. Problem-finding, heuristics and computer modeling, and incubation are prominent. Wallas' four-stage theory (preparation, incubation, illumination, and verification) is often reiterated (Wallas 1926).

In conducting a case study, all of these topics are of potential importance. At the same time, if we pay adequate attention to the issue of time-scale, all of them are transformed. Generally speaking, people think in order to solve problems. The excellent problem solver may have gotten beyond that point: problem solving comes relatively easily. It may be more apt to say that the creator sets himself or herself problems in order to think. The creator is not necessarily a better problem solver. The main point is to develop a new point of view, a perspective from which new problems are seen and old ones are seen in a new light. Charles Darwin was probably not as versatile, eloquent, or brilliant as Thomas Huxley. All he had done was to develop a new point of view and the determination to re-examine every problem from that perspective. Our task as investigators of the case is to discover how this came about.

*Facet 8: Contextual Frames*

In addition to its central focus on some aspects of the development of the creator's work, the case study should take into account a series of contexts or contextual systems (Csikszentmihalyi 1988b) within which the creative work proceeds. The first of these is the set of enterprises most directly relevant to those being studied. The second is the person's oeuvre and overall purposes, revealed in the network of enterprise. The third context is the person's professional milieu—teachers, colleagues, collaborators, critics and so on.

The fourth context concerns the subject's families—the family of origin and the current family—and their role in the development and support of the subject's creative life and work. Wordsworth had as a collaborator his sister Dorothy who also took charge of her brother's domestic needs. Many women who want to do independent creative work have had and still have great difficulty in constructing a life that supports their work and fulfills their other needs. Woolf argued the case in her *A Room of One's Own* (1957), and more recently Hanscombe and Smyers (1987) have done so. The cost to women has been either to forgo other roles—those of wife or mother, for example—or to do it all with inadequate support.

It is not often enough noted that family members may play a role not only in shaping the child but in the creative process itself. Consider these well-known examples:

Darwin and his grandfather Erasmus
Van Gogh and his brother Theo
Einstein and his uncle Jakob
Wordsworth and his sister Dorothy
Anna Freud and her father Sigmund
The Wright brothers
The Brontë siblings

Finally, a fifth context is the sociohistorical milieu, which may have an important influence on the subject's work. Gruber (1981e) argued that Darwin's long delay in publishing *On the Origin of Species* was in large part due to his fear of a hostile reception. But this did not constrain his creative work, nor was he miserable because of it. Freud and many others left Hitler's Third Reich to work productively elsewhere. James Joyce left Ireland and Catholicism for Trieste in order to free himself from a constricting environment. Creative people may feel themselves to be marginal: They are breaking new ground, forging a new point of view that is, as they progress in their work, more and more at odds with their contemporaries and their rulers. This was the case for Galileo, Locke, Descartes. Persecution is a recurrent feature of the history of creative work. But there have been creators who presented their work to the world and found it accepted without great travail, Poincaré, Henry Moore, Edison, Picasso, among many. The person's position in the sociohistorical period depends on the nature of the work, whether it is being made public, how loudly it speaks beyond a specialized audience to the general public, and the degree of religious and political tolerance that impinges on the creator.

The five contexts form a series of frames in the case study method. The subject, of course, both produces these contexts and is shaped by them. But the investigator, too, must be familiar with them as frames of reference for the study. Ideally, they are integrated into the case study as part of the creator's system of thought and meaning that accompanies and affects the work.

In a case study of reasonable length not all of these contexts can be dealt with exhaustively. The investigator must make choices.

### *Facet 9: Values*

Under the heading of values we group affect, aesthetic experience, and morality. We think it reasonable to characterize our approach as cognitive and developmental. For better or worse, this has meant that certain aspects of creative work have been neglected—by us and by like-minded colleagues. In some respects we have been constrained by decades of exalting the notion of "value-free" science, of embracing cultural and ethical relativism, of questioning the meaning of truth unless it is put between quotation marks. The relation between creativity and morality has been neglected as a subject of investigation. Cases like Gandhi are immensely instructive, but there are very few who combine the advancing of truly innovative ideas (such as Gandhi's spiritual doctrine of nonviolence) with determined political struggle (such as Gandhi's leadership of the Indian liberation movement). Consequently, we must think both about the great moralists and about those creators for whom moral concerns are something of an avocation. Even supposing it is true that by the age of forty or fifty most creators have done their best work, the remaining years will leave almost half a lifetime for something else. What will that something be? The dilemma facing creators in today's world is well expressed by Lewis Hyde:

> ... how is the artist to nourish himself spiritually as well as materially, in an age whose values are market values and whose commerce consists almost exclusively in the purchase and sale of commodities? (Hyde 1983, quoted in Gablik 1984, v.).

A similar set of concerns runs through the special issue of the *Creativity Research Journal* on "Creativity in the Moral Domain" (Gruber and Wallace, 1993). For the moment, we simply take note of a need that is already upon us and that will in all likelihood intensify. It follows that students of creativity should look for new ways of incorporating such concerns in their work.

## CONCLUSION

The deliberate choice of the case study method, especially as contrasted with other methods, raises difficult epistemological questions. Here we will take up three issues: The locus of creativity, the investigator's roles, and the problem of reliability and validity.

### *The Locus of Creativity*

Granting fully that creative work takes place within a complex social manifold, can we take a further step and withdraw from our emphasis on the unique creative individual as the creator, i.e., as the locus of creative work? Csikszentmihalyi (1994) has argued that we must do so. First, he proposes a 4 x 3 x 4 matrix for characterizing types of creative work, i.e., forty-eight cells in the matrix. Then he points out that "there are already thousands of psychological studies concentrating in just one of these cells—the quantitative, empirical approach to individual traits" (p.154). He concludes that this means that "creativity is not something that takes place inside the head of a person but is the product of a far larger and more mysterious process" (p.155).

This approach is certainly one option. It has the merit of obliging us to re-examine the excessive individualism of much creativity research. But it is tantamount to arguing that because an organ exists within an organism, the special functions of that organ do not really take place within the organ. Our approach is somewhat different. We avoid as much as possible the reification of a quantity "creativity," in the belief that it is more fruitful to ask what creators do. We agree that there are something like the four levels (culture, institution, working group, person) specified in the 48-cell matrix. But the "person," who is relegated to four of the forty-eight cells, can be located both in geographical and conceptual space and is no less real for that. As for mystery, as much as we strive to demystify creative work, it remains mysterious enough.

*Investigator Roles*

The issue of objectivity is critical. In the case study method, the investigator has two central roles, a phenomenological and a critical one, or, to put it another way, an inside and an outside role (See Table 1.). In the phenomenological role, the investigator strives to enter the mind of the subject of the case to reconstruct the meaning of the subject's experience from the latter's point of view. This is an attempt to achieve objectivity by putting aside one's own biases. In this role, the investigator comes as close as possible to the case.

The equally essential critical role is one in which the investigator stands outside the case to appraise the data and to explain and interpret them. Here objectivity is achieved by putting aside the subject's biases, by distancing oneself from the subject, and by evaluating "from a height." Thus both phenomenological and critical roles aim at objectivity and both entail interpretation. The investigator is continually moving between these two roles.

*Table 1.* Investigator Roles

| *Phenomenological Role* | *Critical Role* |
|---|---|
| Inside the subject | Outside the subject |
| Objectivity achieved by setting aside one's own bias | Objectivity achieved by setting aside the subject's bias |
| Close to subject | Distant from subject |
| Interpretive | Interpretive |

*Reliability and Validity*

Coming from a cognitive and experimental background, it might well be said that we are foolhardy to give up the blessings of precision and verifiability for the vagaries of the case study method, especially with our focus on studies in which N = 1. So long as we restrict ourselves to one case how do we know we are right? Even if we are right about the case, what good is it if we cannot generalize to other cases? A decade or two ago there were very few such cognitive case studies. Now that there are many more, don't we face the problem of bringing them to bear on each other in a synthesis both wider and more penetrating? How do we approach the problem of objectivity—especially when we insist that the student of the case must immerse himself or herself in the world of the creator chosen for study? We have several replies.

First, it could be suggested that immersion in a single case, with the combination of scope and density needed to do it justice, represents a world well lost, as compared with the narrowness and aridity of other approaches. We do not take this position. Instead, we retain the hope of arriving at the kind of documented synthesis that might be attained by bringing different methods to bear on the same problem. To do that, of course, would require reforming many questions. Although we have insisted on the uniqueness of each case, that does leave room for a few interesting generalizations.

For example, a number of case studies have led to the so-called "ten-year rule," the finding that it takes about ten years for an individual or small group to effectuate a really significant revision in their own ways of thought. This is not the sort of finding that one could achieve without going about it one case at a time. On the surface, what with telescoping and forgetting, it is easy for the creator to experience the rush of delight when a great insight finally comes, and to omit in the telling, the years of work that were necessary to reach that moment. Without the accumulation of some twenty or more pertinent and striking cases, we could never have reached this conclusion; without attacking these cases one at a time we could never have accumulated them in this fashion. For more on this see Gruber (1981e), Gruber (1995b) and Sternberg and Davidson (1995).

For another example, consider the idea of networks of enterprise. As a potential factual finding, such networks were staring us in the face for decades, even centuries. But to focus attention on them, to name them and to show how they function in particular cases, required the assiduous application of the case study method, first in one case, then in a number of others, as discussed in this essay.

Finding commonalties among different cases resembles Francis Galton's method of composite portraiture (1883): Photographs of faces are adjusted to the same size and then superimposed by multiple exposures. The resulting composite is "the portrait of a type and not of an individual" (p. 222). Galton applied this method to such "types" as Englishmen, criminals, army officers, family members, and racial groups. Galton argued that these "generic" images are "much more than averages ... They are real generalizations, because they include the whole of the material under consideration" (p. 233). In other words, they are like large statistical tables for considering together all the traits that go into making a particular type. Accidental traits are washed out. And Gallon adds that reducing the size of the eventual print eliminates even more idiosyncratic detail, and so much the better!

Another photographic innovation dating from the same period was the work of Eadweard Muybridge, beginning in the 1870s. He was interested in the analysis of bodily motion. He arranged batteries of cameras so that he could take a series of photographs of a creature in motion—a rabbit, a horse running, or a man walking—so closely spaced that the viewer could see the actual sequence of each movement (De Vries 1971).

Thus, each of these methods has its advantages, one for eliminating detail and representing a static version of a type, the other for capturing very fine detail and representing the precise dynamic sequences in which activity unfolds.

To complete the visual metaphor of the different aspects of a case study, we would have to add something like the medical drawings of a ball and socket joint, or other structures in which part is closely fitted to part. This articulation of parts, both in structure and function, is the most important thing the case study method allows and is completely absent from the most sophisticated techniques of measurement and statistical inference known to psychologists.

The evolution of such structural articulation is what Darwin had in mind when he wrote of "correlation of growth":

> the whole organization is so tied together during its growth and development, that when slight variations in any one part occur, and are accumulated through natural selection, other parts become modified. (Darwin 1859, p. 143).

It is this kind of almost perfect fitting that we would like to accomplish through the case study method. This is a far cry from the modern concept of correlation as used in research on creativity, in which a value of $r = .25$ to $.50$ may be hailed as statistically significant.

It is the scope and density of the creator's thought that permits the student of the case to search for ideas analogous to the beautiful mechanisms of adaptation that so amazed Darwin and his contemporaries. Darwin's notebooks about evolution (Barrett et al. 1987; see also Gruber 1981e) reveal him as a person also thinking about thinking and provide some useful guides for the study of other cases. In this essay we have made much use of the Darwin case. The interplay among his organizations of purpose, affect, and knowledge, as well as his manifold relations with other scientists, are richly brought out in his early notebooks (Gruber 1981e; Keegan and Gruber 1983).

Throughout this essay we have made assumptions that may be seen as contradictory. On the one hand, the creator sets a high level of aspiration, and expects or at least hopes to be efficacious, to make a difference. Yet the yield for a lifetime of effort may be small. At one point in his early notebooks Darwin wrote acceptingly of this dilemma:

> Mention persecution of early Astronomers.—then add chief good of individual scientific men is to push their science a few years in advance only of their age. (C Notebook, p. 123, written about June 1838; in Barrett et al. 1987).

A little earlier he had remarked that this slowness of thought was painful to undergo:

> ... this multiplication of little means & bringing the mind to grapple with great effect produced [in long periods of time, Eds.], is a most laborious, & painful effort of the mind ... (C Notebook p. 75, written about May 1838; in Barrett et al. 1987).

Easy or hard, the interconnectedness of all life forms puts constraints on rate of change. In our era we have our spotted owl struggle to teach us how difficult it is for people to accept this constraint. Darwin had already remarked on a similar situation: "... even one species of hawk decreasing in number must effect instantaneously all the rest" (D Notebook, p.135, written Sept. 28, 1838, as part of the celebrated moment of Malthusian insight; in Barrett et al. 1987).

Our emphasis on the role of the individual in the creative process should not be taken to mean that only lives that make a big difference are creative and worthwhile. Making small differences and even innovations that counteract change may be the most important forms of creative work in the years of the century that is almost upon us. If creative work is to be organismic, to express this feeling for the organism, perhaps it must be, for the most part, modest.

In a striking passage, Wittgenstein expressed this feeling:

> When we first begin to believe anything, what we believe is not a single proposition, it is a whole system of propositions. (Light dawns gradually over the whole.) (Wittgenstein 1969, 21).

# Inching Our Way up Mount Olympus: The Evolving-Systems Approach to Creative Thinking

*Together with Sarah N. Davis*

Karl Duncker began his classic monograph *On Problem-Solving* (1945) with this remark: "To study productive thinking where it is most conspicuous in great achievements is certainly a temptation, and without a doubt, important information about the genesis of productive thought could be found in biographical material. But although a thunderstorm is the most striking example of electrical discharge, its laws are better investigated in little sparks within the laboratory."

The familiar metaphor likening the creative moment to a bolt of lightning deserves scrutiny. Taken right, it is apt not only for the mystification of magical moments but also for the demystification of the creative process.

A bolt of lightning is by no means a unitary event. It has inner structure and temporal development. There is a period of preparation in which electrical charge is built up; the charge is not a "trait" of the thundercloud, but a relationship between cloud and ground below, or between cloud and cloud (i.e., a difference in electrical potential). The buildup of potential difference involves a positive feedback mechanism in which myriad collisions of ice pellets or water drops produce the charge; these earlier events, though of low intensity, prepare the way for intensification later on.

In one type of flash, a downward stroke proceeds in branching steps from cloud to ground; when this "stepped leader" comes near the ground, "an upward discharge jumps from the target object to meet it" (Orville 1977). This upward stroke is the brilliant event that we normally see as lightning—the result of all that preceded it. Usually there are three to four strokes within a flash (sometimes many more) that can be detected not by the naked eye but by high-speed photography. The aftermath of lightning, thunder, comes a little later, involves quite different processes, and lasts much longer.

Not only is the individual lightning stroke complex, it is part of a more complex system—the thunderstorm as a whole. And each storm is part of a still wider worldwide system of storms—a few thousand going on at any given time—thus maintaining a state of dynamic equilibrium, the approximately constant negative charge at the earth's surface.

There is in Duncker's use of the creativity-lightning metaphor a double irony: first, because Max Wertheimer, who was Duncker's mentor, in his classic *Productive Thinking* (1945) made ample use of historical case materials (Galileo, Gauss, Ein-

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stein); second, because Duncker's own work was primarily an exemplary exercise in careful qualitative analysis of problem-solving protocols. Neither Duncker nor Wertheimer made systematic experimental laboratory attempts to manipulate the conditions of creativity or to "measure" the creativity of the solutions arrived at by their subjects.[1]

In our constructionist *evolving systems approach*, the creativity-lightning metaphor holds good so long as it is understood correctly. Insights, like lightning strokes, represent not a break with the past but the steady functioning of the creative system at work. By the same token, emphasis is withdrawn from the supposed single great stroke of insight and transposed to the many moments of insight that occur in the course of a creative effort. Elsewhere, Gruber (1981k) has estimated that as many as one or two noteworthy insights per day (or 500 per year, coming to 5,000 in a project taking ten years) may be characteristic of highly creative people. Moreover, each moment of insight has its own internal structure, its affective and cognitive microgenesis. The fact that it is a process in time means that the creative person has some measure of control over it; as it develops, one can welcome or reject it, shape and steer it. Finally, sudden moments of sharp insight must take their place within the complex, evolving system that is the creative person at work.

## AIMS

This chapter has three aims. First, we want to describe and illustrate our use of the case study method in the study of creative thinking. Second, we want to present a brief version of the *evolving-systems approach* to creative thinking as it has been elaborated thus far. Third, we want to discuss some of the major difficulties of the case study method and some next steps to be taken in developing the *evolving systems approach*.

We have chosen to take up the case studies first and to sketch the *evolving systems approach* at the end of the essay. This reflects the actual course of events, as this approach grew out of the case studies (Gruber 1981e). But it may help the reader if we make certain points clear at the outset.

Although we emphasize the fact that almost all creative products result from long periods of purposeful work, we do not deny the role of chance events and spontaneous play. We do insist that such occurrences must be incorporated into ongoing enterprises under the control of the creative person.

It would be foolish to deny the role of greatly cultivated skills as part of the creative process. But in our competence-oriented profession, working within a "can do" society, it is all too easy to overemphasize skill. For example, Henri Poincaré probably was Einstein's nearest rival in steps toward the theory of relativity. Einstein was a competent mathematician, but Poincaré was superb. What the latter lacked was the

1. W. Köhler was Duncker's other mentor. Although his subjects were great apes and not great men, in other respects his methods were similar to those of Duncker and Wertheimer: careful observation and painstaking interpretive reconstruction of pathways taken.

right sense of direction. To take a second example, this one from the arts, the notable forgers of history—individuals whose forgeries have found their way into the great museums of the world—obviously have had skills equal to or even surpassing those of the artists they have copied. Unfortunately, their exercise of these skills has not been mobilized for creative work, but for copying.

This is why we insist that the central problem for the study of creative work is to understand how one organizes and reconstructs a life to form a system of knowledge, purpose, and affect that can do creative work. Of course, this is not one problem, but many, and the name we have given them is the *evolving-systems approach* to creative work.

## THE CASE STUDY METHOD

Our cognitive case studies of creative work, to be reported here, treat the materials of the life histories of our subjects as problem-solving protocols of long duration, requiring probing hermeneutical interpretation in order to reconstruct the events we hope to understand. We have long insisted on three fundamental propositions:

1. Each creative person is a unique configuration.
2. The most challenging task of creativity research is to invent means of describing and explaining each unique configuration.
3. A theory of creativity that chooses to look only at common features of creative people probably is missing the main point of each life and evading the main responsibility of research on creativity.

Nevertheless, there are two sorts of commonality to be considered. First, even investigators interested in the understanding of uniqueness may use similar strategies in their inquiries. Indeed, it is in some degree necessary to do so in order to arrive at the conclusion of uniqueness. Second, even unique creative individuals may share some important characteristics with other unique creative people. Or, perhaps better put, different episodes of creative processes may resemble each other in some interesting respects. These commonalities may be important as the context within which the unique processes appear.

One of the main aims of this chapter is to describe a set of case studies that illustrate a common strategy that for want of a better term we may call the "cognitive case study method." The process of description (i.e., writing this chapter) will, we hope, make more explicit the strategies entailed in the practice of a psychological craft that we have been developing for some thirty years.

We focus on a group of nine doctoral dissertations completed between 1962 and 1985 under Gruber's direction. We omit dissertations now in progress on Erasmus Darwin, Freud, Shaw, van Gogh, and Piaget. As preparation for writing this chapter, Davis interviewed the authors of seven of the nine dissertations on which we draw.

We have had to face one difficulty that is both methodological and pedagogical. A single teacher cannot have expert knowledge of each of the diverse cases described herein. Accordingly, on each advisory committee someone was included who did have the necessary expertise; we might better say some of the necessary expertise, because no one investigator fully knows a case. Probably the best-studied case in the history of science is that of Charles Darwin, partly because of the wealth of documentation he left, and partly because of the general interest of his work for so many different disciplines. It has taken a small army to get as far as we have in Darwin scholarship. And it may well be that the most important work is yet to be done.

This brings up a second methodological-pedagogical point. When this long project began, we used to speak bravely of studying "the cognitive economy as a whole." But it is evident that this is an abstract ideal, not to be forgotten, but honored in the breach. Each case study must choose a few foci and commit many painful omissions. A "few" foci should always mean more than one, for it is in the interplay of different aspects of the case that it comes alive.

## THE CASE STUDY METHOD IN RELATION TO OTHER METHODS

The merit of the case study method lies in its ability to consider a large number of issues together and in their relationships. The question may well be put: Why not apply the highly developed methods of multivariate analysis? There are four principal reasons. First, we are concerned with process rather than traits. Second, multivariate techniques, with their reliance on measurement, assume that it is appropriate and possible to measure the relevant population on the relevant traits, which seems utterly implausible to us, for reasons given later. Third, we place great emphasis on the need to understand creative people at work in their own contexts; the emphasis on measurement decontextualizes what is being studied. Fourth, the need for large numbers of subjects forces the use of inappropriate populations, such as U.S. Coast Guard trainees or unselected high school students. Although these are certainly valuable and interesting human beings, usually we can have no guarantee that the sample taken includes a single person who is functioning creatively. Better to start with widely agreed-upon cases.

In the study of creative work, each case can be distinguished from the others on some variable for which it makes absolutely no sense to measure the others, and in fact no provision for such a measure could ever be envisaged until that case comes under scrutiny. As the poet Blake wrote in *The Marriage of Heaven and Hell*, "One Law for the Lion and Ox is Oppression." More important, what really counts in each creative life is the pattern in which knowledge, purpose, and affect are organized, as well as the fit of the pattern to a set of tasks that do not preexist but are constructed by the creative individual in the course of the work.

For example, when young Darwin set out on the voyage of the *Beagle*, he enjoyed an ample and unprofessional vagueness in his goals (Darwin 1934). Young Huxley, on the other hand, setting out on the voyage of the Rattlesnake, was crisp, professional, and brilliant (Huxley 1935). Any awards committee would have chosen Huxley for the fellowship and put Darwin on the waiting list—and never would have known enough to regret the choice. We cannot conclude from this that initial vagueness is somehow always better than initial precision, or the reverse. But the two stories can alert us to the relation between early goals and later achievement; understanding how that works out in a given case is a task for the student of the case.

Huxley's brilliance and precision stood him in good stead. His career was brilliant and creative. When in 1856 he finally heard of Darwin's theory, he exclaimed, "How stupid not to have thought of that!" He then became an effective proponent of Darwin's ideas. Although he explained it beautifully and insisted on its plausibility, he never quite espoused the theory of evolution through natural selection, and this fact helps, perhaps, to explain why he did not invent it. He was penetrating enough to see the unsolved problems in the theory—but so was Darwin. Huxley was probably too committed to an early form of positivism (he wrote a biography of Hume) to be comfortable with a theory that was such a web of long-range inferences. This tough-mindedness was a good quality for Huxley and served him well. Although it was Darwin who had the greater impact, we cannot say that Huxley would have been better off to have been more like Darwin.

There have, of course, been numerous attempts to study aspects of the creative process in the experimental laboratory. We refer to our own attempts to do so as "quasi-experimental," and this for two reasons. First, our primary methodological commitment is to the case study method, and we wish to avoid getting so drawn into any particular experimental program as to forget our goal of understanding the person as a whole and in context. Second, the source of the problems taken up in this way is not some ongoing paradigm of experimental research, shared by a number of investigators, but the requirements thrust upon us by the case. The very fact that we are studying an unusual case and trying to understand it as a whole sometimes draws attention to neglected issues that are suitable for experimental or other narrow-beam approaches. By taking up such issues experimentally, we hope both to illuminate the case and to contribute to a wider field.

One example of this kind is Gruber's study of the process of synthesis of different points of view. In his studies of Darwin, Gruber has been quite struck by the point that the same panorama of species looked quite different from different points of view (Darwin 1859). For example, the Galapagos Archipelago flora and fauna change their aspects if one examines them in their relation to South American species (the nearest continent) or if one examines them only in their island-to-island relationships. In a striking passage, Darwin describes his own puzzlement over such matters. The passage (Darwin 1859, 50) begins, "When a young naturalist"— obviously himself—and goes on to explain the initially paradoxical observations that occur if one moves from place to place, naturalizing, and how the paradoxes of taxonomy can be resolved by altering one's point of view and by making use of the expert knowledge of others with different points of view. This has become, in Gruber's laboratory, a study of the cooperative synthesis of points of view, using quite different materials from those studied by Darwin, but always with an eye cocked for understanding the problems of synthesis (Gruber 1985c; Gruber and Sehl 1984).

Davis (1985) wished to study the way in which the meaning of a story evolves as one reader encounters the story repeatedly. As part of her method, Davis wanted to use an interruption method in which the reader is stopped from time to time and asked about various issues concerning character, plot, setting, and symbolic meaning. But it was important to know if, or how, the interruption method affected the reader's responses to the story. Davis explored this issue in a subsidiary experiment with other subjects, thus demonstrating the feasibility of the approach.

The case study method as we have practiced it is quite distinct from psychoanalytically oriented psychobiography. Such studies have emphasized the underlying motives of the creative person, their childhood origins, and their neurotic character. Our focus of attention has been on how creative people do their work, rather than on why, and on the developmental process within the career, rather than on that leading up to it. We are far from denying the importance of unconscious processes. We nevertheless see them as occurring in a person struggling and often succeeding in taking command of them to make them serve the interests of consciously and freely chosen enterprises. By the same token, we take seriously the consciously held systems of belief and intentionality of the creative person. This, in turn, requires us to take a phenomenological stance in reconstructing subjects' experiences from their own points of view. In these matters, our position resembles that of Rothenberg (1979). These methodological questions have been discussed at length by Wallace (1985).

## CASE STUDIES OF CREATIVE WORK AS DOCTORAL DISSERTATIONS

Are case studies of the creative process good subjects for doctoral dissertations? A number of difficulties immediately appear. Training in psychology or other social sciences does not prepare the investigator for this kind of work; for example, the hermeneutical skills of interpretation are remarkably absent from courses in research methods. Each case requires immersion in a highly specialized subject matter, and this takes considerable time. Problems of this kind can be solved if the student is willing to make the necessary investment; it is important that the supervisor not understate the difficulties. At least one question remains unanswered: How can we make "real science" out of studies of unique individuals?

Admittedly, the diversity of cases and treatments poses a problem, but it also presents an opportunity. Consider a certain cartoon in the *New Yorker*. In the first four panels we see a naked man standing on some flotsam in a wide ocean, slowly fitting together the pieces of flotsam in the sea around him like a jigsaw puzzle. Thus he constructs the little island that will have to serve as his terra firma. Then comes dawn, and he discovers all around him an ocean full of other naked figures, all doing the same thing.

We can take this cartoon as emblematic of the diversity of our cases and of their relative isolation from each other. Or we can take it as standing for the next task: fitting the islands together.

To explore these and kindred questions, we have chosen to describe several dissertations, all completed under Gruber's direction. We hope to show that at least a start has been made at solving these problems, and that it is worth the effort. The discussion is organized under three main headings: basic commitments and organizing schemes, the role of metaphors in creative work, and the interactions of creative individuals with their worlds.

*Benjamin Franklin's Scientific Work*

Donald Hovey's dissertation was completed in 1962 at the University of Colorado. It then seemed quite daring to introduce data from the history of science into a dissertation done in an experimental psychology program, and so a compromise was agreed on by Hovey and the faculty involved. The case study would be combined with experimental studies of problem solving related to the case. Accordingly, the thesis bore the hybrid title "Experience and Insight: Experiments on Problem-Solving and a Case Study of Scientific Thinking."

Hovey had been struck by some interesting similarities in the way that Benjamin Franklin solved several widely disparate scientific problems. In addition, Hovey was skeptical of the impression given by Franklin's autobiography (1874) and by later biographers that Franklin's interest in the science of electricity had been provoked by a single, rather late encounter that had led quickly, within four to six months, to his momentous discoveries concerning electricity. From his discerning reading of the documentary evidence, including some material newly available from the work of Cohen (1956) and Labaree (1959), Hovey drew up the following picture:

1. Franklin applied the same schemata in solving disparate problems. It was already well known that when water begins to flow in a canal, the water at the lower end must move first, making way for the water behind it, and so on. This results in the counterintuitive fact that the elapsed time before onset of flow at successive points increases as one moves upstream (i.e., in the direction opposite to that of the flow itself). Franklin applied this model to the time of onset for a storm seeming to move from north to south (wind comes out of the north, storm begins earlier in the south). He also applied it to a more speculative hypothesis on the circulation of electrified "particles of air" in producing the aurora borealis. Franklin's work on the storm-movement problem was set off by an unusual coincidence of a storm and an eclipse of the moon; the careful timing of the eclipse in various places, together with coincidental observations of the advent of the storm, gave rise to the anomalous data that Franklin's model could explain. Perhaps one should add that Franklin's immersion in problems of air circulation had earlier played a part in his invention of the Franklin stove.
2. Hovey gave a version of the fluid-movement problem to experimental subjects. They were given prior guided experience with the water-in-canal problem, leading to successful solutions. Nevertheless, they were not able to solve the storm-movement problem. Of course, this corresponds to the historical facts, because

it required a person like Franklin to take the same step in history. From this, Hovey concluded that having the necessary components for solving a problem does not automatically lead to a solution. Here he was explicitly siding with Maier (1940) in an ongoing debate. He also drew on Birch's (1945) revision of Köhler's work on chimpanzees: Birch showed that even in innovative and insightful problem solving, the apes required a background of experience with the materials involved.

3. Hovey took the next step of examining the hypothesis that Franklin must have had a long-standing commitment to certain scientific ideas. This would at once explain his originality in solving the storm-movement problem and his apparent speed of work after he began his electrical inquiries.
4. The conceptual structure of Franklin's theory of electricity includes the following schema:
   a. Atomism
   b. Conservation
   c. Equilibrium
   d. Circulation
   e. Heat and electricity regarded as material elements
   f. Highly static view of microstructure of atmosphere
   g. Reliance on principles of attraction and repulsion
5. At least some of these ideas, notably conservation and equilibrium, could be found in Franklin's earlier thinking about these matters. In his pamphlet *A Dissertation on Liberty, Necessity, Pleasure and Pain*, Franklin concluded:

> 1. A Creature when endu'd with Life or Consciousness, is made capable of Uneasiness or Pain. 2. This Pain produces Desire to be freed from it, in exact proportion to itself. 3. The Accomplishment of this Desire produces an equal pleasure. 4. Pleasure is consequently equal to Pain. (Hovey 1962, 76, citing Labaree 1959)

This was written in 1724 when Franklin was eighteen years old. It bears some remarkable formal similarities to Franklin's analysis, over twenty years later, of the Leyden jar.

6. Hovey supplemented this historically based study with some experimental work on general aspects of problem solving. He used materials similar to those used by Maier and Duncker. He made a careful analysis and introduced experimental control of the models available to the subjects, and drew the following conclusions:

> The nature of the problem solution is in part determined by the availability of cognitive models to the individual ... The initial solution tendencies in a problem are the result of the interaction between the model initiating the problem and the situation characteristics. Whether a solution tendency persists to become the problem solution is dependent upon the degree of functional

> similarity between the initial solution tendency and subsequently appearing aspects of the problem situation. Problem-solving behavior in these experiments is not a response to objective stimuli within the situation, nor is it the reflection of dominant response tendencies brought into the situation. Instead, the behavior is coordinated to functional relationships arising jointly from the situation and from the individual's models. (Hovey 1962, iii-iv)

It should be added that Gruber and Gruber (1962) had pointed out that Darwin, too, had applied the same schemata repeatedly. In one striking instance during the Beagle voyage in 1834, Darwin had developed a theoretical model of the formation of coral reefs. His theory of evolution through natural selection bears a strong point-for-point resemblance to the coral reef theory. Yet when Darwin became committed to the search for a theory of evolution, his first moves by no means exhibited this formal structure. It seems that even well-developed and well-mastered models and schemata are not automatically applied to new problems.

*The Thought Form of Gradualism in Charles Darwin's Life Work*

In writing *Darwin on Man*, Gruber (1981e) focused more on the changing structures of belief systems, or of theoretical models, than on the issue of recurrent themes. During the same period, however, Holton's interesting work *Thematic Origins of Modern Science* (1973) appeared. Also, in Ferrara's work (1984) on "networks of enterprise" we found that it is difficult if not impossible to give a good account of the organization of purpose in the form of the person's manifold projects and enterprises without taking into account themes that cut across these boundaries. These developments, together with our group's general concern for ensembles of metaphors and other figures of thought, set the stage for Keegan's efforts.

In a number of areas there has been a persistent search for units of analysis appropriate for description of the organization of knowledge and beliefs. In developmental psychology, in problem-solving research, in work in artificial intelligence, and in research on expert systems, various approaches have been explored. These can be divided into two main categories: the specific and the general. Among the specific kind are schemata, scripts, and plans. Abelson (1981, 715) writes that "one simple form of scheme is the script embodying knowledge of stereotyped event sequences."

Among the general kind are to be found principles, structures, themes, and Keegan's candidate, *thought-forms*. As Keegan describes the idea of a *thought-form*, it is closely related to Holton's effort to search out the basic themes of modern science, except that "the thought-form can be viewed as the incarnation of a theme within an individual" (Keegan 1985, 29).

In order to see one thought-form adequately, it is necessary to situate it in its intellectual context and examine how it functions in the work of the thinker. In his dissertation, *The Development of Charles Darwin's Thinking on Psychology* (1985), Keegan set out to understand Darwin's thought-form of gradualism by means of the following steps:

1. He traced the recurrences of Darwin's use of the thought-form in a variety of contexts.
2. He examined one of Darwin's enterprises in some detail, with particular attention to the thought-form of gradualism. With an intentional allusion to Freud's life, Keegan called this enterprise "Darwin's Project for a Scientific Psychology." Keegan studied Darwin's effort to construct a science of psychology as it evolved over a period of five decades.
3. He divided Darwin's life into five major periods and examined the recurrences of the thought-form of gradualism within each.
4. He examined the thought-form of gradualism in relation to other important thought-forms.
5. He compared the psychology enterprise to Darwin's other enterprises.
6. He transcribed and analyzed the full text of Darwin's *baby diary*, with special attention to its place in Darwin's psychology enterprise and its relevance to the thought-form of gradualism.

Keegan discussed two variants of the gradualism thought-form: stepwise change and change by "insensible" (i.e., infinitesimal) amounts. For Darwin, as long as the steps were small enough, both kinds of change qualified as gradual. This way of thinking inevitably calls into play the idea of scale, because a large step on one time-scale may be small on another. Earthquakes are good examples of this point, and Darwin had experienced an impressive one in Chile, during the voyage of the *Beagle*. An earthquake that changes the level of the ground by two feet is an enormous event from the point of view of momentary human affairs, but on the geological time-scale it may be an almost imperceptible part of a process of elevation lasting millions of years, Darwin argued.

Outside the field of psychology, of course, the thought-form of gradualism was widespread in Darwin's thinking (See Table 1.).

Among the other thought-forms Keegan discusses as part of Darwin's thinking are evolutionism, or progressionism and materialism. For a full development of all of these it was necessary for Darwin to assume that a scientific psychology was possible, and to make that assumption was tantamount to setting to work on its elaboration.

When Darwin began his theoretical efforts (first in geology), his earliest and always his primary commitment was to gradualism, not to any specific mechanism of change, not even to his favorite, natural selection. This point helps to make psychological sense out of some of Darwin's apparent waverings. Rather than switching allegiances from one belief system to another, he was moving around within a hierarchically organized system of beliefs and intellectual commitments.

*Table 1.* Varieties of gradual change

| *Phenomenon* | *Cause* | *Appearence* |
|---|---|---|
| Earthquake | Migration of fluid magna | Stepwise |
| Terraces at Coquimbo | Denudation by sea action | Stepwise |
| "Roads of Glen Roy" | Denudation by sea action | Stepwise |
| Coral reef formation | Deposition of calcareous material | Insensibly gradual |
| Formation of vegetable mold | Deposition of extracta | Insensibly gradual |

In *Darwin on Man* (1981e), Gruber's main emphasis was on the reconstruction of a series of changes in a belief system: Darwin's successive attempts to construct a workable theory of evolution. As compared with this emphasis, Keegan's special contribution is to examine one mechanism at work in the process of theory construction, the recurrent application of a particular thought-form.

Within Darwin's epistemological framework, this reiteration had two merits. On the one hand, it led to the solution of particular problems, as illustrated in Table 2. On the other hand, by solving diverse problems in the same way, it helped to establish general laws and to lend credibility to a coherent view of natural change, summed up in Darwin's thinking in the phrase "nature makes no jumps" (Table 2.).

*Table 2.* Time-scale and perception

| *Event* | *Human perception* | *Geological effects* |
|---|---|---|
| Earthquake | Vivid and significant | Trivial |
| Gradual denudation | Imperceptible | Highly significant |

Keegan traces the development of the thought-form of gradualism in Darwin's thinking during the voyage of the *Beagle* and its application to the evolution of mind, especially in the few years following the voyage. To say that Darwin's own thinking changed "gradually" is not to imply that the change came easily, without painful struggle. In 1838, in his second notebook[2] on evolution, Darwin wrote:

2. Charles Darwin's early notebooks were read in the original manuscript by Howard Gruber in the Cambridge University Library Manuscript Room. They have now been published in various forms, of which the most generally accessible are Gruber (1981e) and Gruber (1974). In addition, there is a two-volume paperback edition of the same, published by the University of Chicago Press: Barrett and Gruber (1980) and Gruber (1981e).

> This multiplication of little means & bringing the mind to grapple with great effect produced is a most laborious & painful effort of the mind (although this may appear an absurd saying) & will never be conquered by anyone (if has any kind of prejudices) who just takes up & lays down the subject without long meditation. (Darwin manuscript, 1837, C-notebook, 75)

This passage was written only a few months before Darwin decided to keep a separate notebook dealing with psychological issues and mental evolution. The period of the second notebook can be seen as exhibiting complexities and tensions requiring a new branching in Darwin's network of enterprise, which occurred most explicitly when he began the "M Notebook," first of two on man, mind, and materialism. Keegan gives a good account of the branchings within the psychology enterprise as it developed further, which we omit here for reasons of space. He also presents a useful picture of Darwin's enterprises as a whole (Figure 1.). In so doing, he suggests how the thought-form of gradualism permeated the whole of Darwin's thinking.

It is useful to ask what motivated Darwin to keep his earthworm project going for over forty years from the publication of his first paper on the geological function of worms (Darwin 1837b) to his final book, amplifying the same subject (Darwin 1881) and combining it with an account of the behavior, even problem-solving behavior, of earthworms. Keegan proposes that the long-term motivating context of the project was twofold: first, Darwin's interest in the thought-form of gradualism; second, the complex assimilation of the project into Darwin's network of enterprises by linking up the geological and the psychological enterprises through the mediation of the worm.

Up to this writing, the network of enterprise has been easier to write about than to diagram perspicuously in all its complexity. Keegan's effort, by painting with a broad brush, gives a useful picture of Darwin's network as a whole. We have yet to find a way of achieving this goal at the same time as we capture the fine structure in its enormous diversity and manifold interconnectedness.

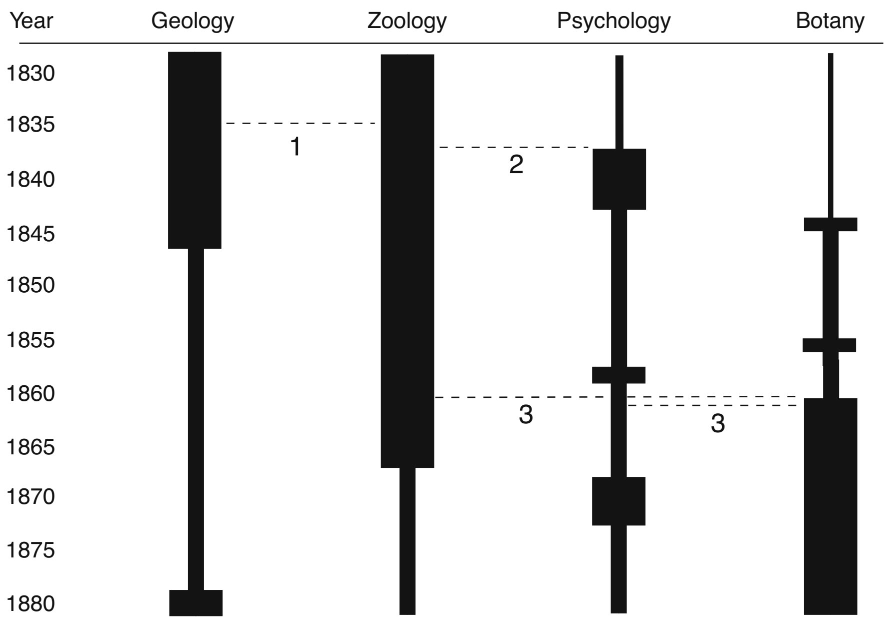


*Figure 1.* Darwin's network of enterprises: 1831 - 1882. The enterprises are arranged from left to right in the order in which they emerged. The first major connections among enterprises are indicated by dotted horizontal lines. From left to right, the dotted lines stand for (1) the coral reef theory, (2) the M Notebook, and (3) the fertilization-of-orchids book. Solid vertical lines indicate the intensity of work during a given period of time. The thickest lines show periods of most active work, moderately thick lines indicate periods of dormancy, and thin lines indicate embryonic periods of the enterprises.

## THE ROLE OF METAPHOR IN CREATIVE WORK[3]

How do metaphors actually function in creative work? Much has been written about the essential nature of structure of metaphor, and sharp lines have been drawn between such ideas as theory-constitutive as opposed to expressive functions of metaphor. In our view, metaphor can serve numerous functions that are not mutually exclusive. The "profile" describing the use of metaphor almost certainly varies from

3. These ideas have also been developed in Gruber (1987b), written after the present essay. Jeanne Hersch's essay (1932) on Bergson's imagery studies the relation between Bergson's metaphors and his ideas in a fashion uncannily like our own; we discovered it after the present essay was written. We have searched, without success, for other examples in the psychological literature.

one creative person to another and must also change in different phases of the creative process. This diversity suggests the need for the case study method in order to comprehend the way metaphor actually works in creative processes.

Let us consider some of the possible roles for metaphor. First, metaphor may serve directly as a modality of thought. Just as some thinking goes on directly in visual images and some directly in words, just as Wordsworth seems to have thought directly in iambic pentameter—some thinking can take an immediate metaphoric form. Second, a metaphor may play a synthesizing role, as when it expresses a link between disparate domains. Third, metaphors may play an analytic role, as when a complex idea is broken up into components, each expressed by different metaphors.

Fourth, metaphors may concretize abstract ideas; they may lend palpability to otherwise vague ideas. Fifth, they may illuminate the abstract idea that connects different groups of concrete experiences. Sixth, by highlighting the mismatch between the literal and metaphoric forms of an idea, they may both stimulate the production of new ideas and function as a way of testing a system of beliefs.

Seventh, metaphors may serve a theory-constitutive role, as when they enter directly into the argument being put forth. Eighth, on the other hand, metaphors may play an expressive role, as in cases in which the idea in question has been developed in some other form and is restated metaphorically for purposes of emphasis or communication. Finally, metaphors may play an affective role, as when the evocative power of a metaphor charges an idea with new excitement.

The reader who pauses a moment will have little difficulty extending the foregoing list. It is not intended to be complete, but only to give an initial idea of the complexity and variety of the functions of metaphors in creative work. By now, also, the reader will have recognized that we use the term "metaphor" in a broad sense, much as in *Metaphor and Thought* (1979), where the very distinguished list of authors typically avoided defining the term, or in Leary's ongoing project on metaphors in the history of psychology (D. Leary, personal communication), in which a very catholic idea of the domain of metaphor is made quite explicit.

*Darwin's Irregularly Branching 'Tree of Nature' and Other Images of Wide Scope* was the title of Gruber's essay in a work on aesthetics in science (Gruber 1978a, see page 241). A great deal of attention had previously been given to one of Darwin's metaphors: natural selection. We might ask (Young 1985): Is it a metaphor, properly speaking? In what sense does Nature select? Was Darwin personifying Nature? His other metaphors had been largely neglected.

But Darwin used at least eight major metaphors in developing the theory of evolution through natural selection: tree, tangled bank, wedging, struggle, war, contrivance, and both artificial and natural selection. Overemphasis on the metaphors representing triage in nature—war, struggle, and selection—misrepresents Darwin's thinking. In his theory, it is the interplay between the forces of explosive growth, variation, and enrichment, on one side, and forces of selection, on the other, that produces the evolving panorama of organic nature.

Gruber used the term “image of wide scope” where he might just as well have said “important metaphor.” An image is “wide when it functions as a schema capable of assimilating to itself a wide range of perceptions, actions, and ideas” (Gruber, 1978). In the present discussion we have used “metaphor” in approximately the same sense. There is probably a place for a special term such as “image of wide scope,” distinct from metaphor, to refer to the potential vehicle of a metaphor that has not yet been formulated or to refer to a supple schematization (such as “network”) that might enter into a number of metaphors. But in this essay we go no further toward systematizing the variety of figures of thought in creative work.

*Ensembles of Metaphors in William James’s Thought*

William James both developed and communicated his theories through extended use of metaphors. In his dissertation, Osowski (1989) undertakes a study of the twelve-year process (1878-1890) whereby James produced *Principles of Psychology* (1950). He shows the development of James’s thought, the questions he was trying to answer, and the role that metaphors played in this process.

Osowski examines the linkages between theoretical ideas and metaphors. He traces the use of metaphors in *Principles* in relation to the emergence of major conceptions in James’s theory of mind: continuity, change, unity and identity, selection, and relationships among elements of thought. The development of these concepts was coordinated with the generation of an ensemble of four metaphors: stream of thought, flight and perching of a bird, fringe of felt relations, and herdsman. These major metaphors each embraced subensembles or families, so that several aspects of an idea could be developed through the use of similar but differing images.

The stream-of-thought metaphor was a large and central node around which numerous other metaphors circulated. These satellite images were the following: train, chain, path, current, channel, line, procession, kaleidoscope, and fabric. Through flexible use of these metaphors, James was able to capture concepts of continuity, constant change, direction, connectedness, pace, rhythm, and flow. The stream metaphor allowed James to describe the phenomenology of thought, especially his sense of its fluidity. Complex thoughts could not be built by chaining simple thoughts. James wanted to show that connections in mind are multilinear; the stream, with its branchings and complex flow, could express this idea.

The stream metaphor, however, was not capable of encompassing all of James’s ideas. It was necessary to join it with others. In Volume 1 of *Principles*, James linked the stream with both the train and chain metaphors. In Volume 2, another subensemble was more prominent: the stream linked with a path, hydraulic current, and an electric current.

Both the chain and train metaphors helped to clarify the idea of the stream by presenting alternative notions of movement that were antithetical to James’s view of fluidity. More positively, they also represented other aspects of mind, such as association and neural functioning, that James wanted to combine with his phenomenological efforts. James also exploited similarities that linked the stream and train: Both move, have their own sources of power, and are able to change pace and direction. He called on the train and chain metaphors to describe a limited linearity in some phases of mental functioning: "There are, then, mechanical conditions on which thought depends, and which, to say the least, determine the order in which is presented the content or material for her comparisons, selections, and decisions" (James 1950, Vol. 1, 553).

Osowski argues that James was unable to find one unifying image to encompass his ideas about both phenomenology and neural functioning. The train, in fact, became two distinct images for James. There was a mechanical or operational train metaphor, used to represent association, and a structural train metaphor, used in contrast to the stream.

Stream, path, and current were used in Volume 2 to explore further the notions of change, continuity, and connection. Both a stream and a path are continuous, but for James what was salient in the path metaphor was its linearity. This helped him deal with the structure of the neurophysiological machinery.

In Volume 1, when James was primarily concerned with phenomenology, the stream metaphor was dominant. In Volume 2, James's concern with neural functioning became more prominent. The path is like the stream in that it remains and may be modified by movement upon or within it. It goes beyond the stream in having a firm structure that can be revisited. This idea of revisitation was important for James because his view of memory and perception entailed reproductive association, and in his neural circuitry model it was necessary to posit a structure that could be modified by repeated use. As James well knew, the Heraclitean flux of the stream conflicts with the requirements of a stable self, and he needed an ensemble of metaphors that could assimilate both.

Current functioned as two distinct metaphors, one denoting the movement of a portion of a larger body of water, the other as the flow of electricity. When the current metaphor was used in the hydraulic sense, James's emphasis was on phenomenology, and he used such terms as "gushing," "swelling," and "bottle up." These water metaphors were particularly evident in the chapters on the will, perception, and emotions—all of which stressed phenomenological over neurophysiological models. For example, in action after deliberation there is a building of tension (as in a dam) and a bursting or flow when the tension becomes too high.

Taken together these metaphors allowed James to expand his explanation of neural mechanisms. The path as an image provided the aspect of a structure that remains after use, yet can be modified through use. The electric current metaphor provided a set of dynamic rules, including notions like excitation and summation. The water current metaphor represented concepts such as tension, blockage, and threshold in both universes of discourse—physiological and phenomenological.

*Images of Mind in John Locke's Thought*

Locke's ideas about cognition underwent dramatic change during the course of his work. He began as a nativist, believing that God implants in man necessary knowledge and moral laws. He shifted to sense empiricism, holding that all knowledge arises during the lifetime, from sense perception. He came ultimately to believe in sense experience as a primary and certain way of knowing. In *An Essay Concerning Human Understanding*, begun in 1670 and completed in 1690, he takes the position that men "by the use of their natural faculties, may attain to all the knowledge they have, without the help of any innate impressions" (Locke 1965).

The development of Locke's theory of cognition was directly influenced by what he perceived to be the causes of men's disregard for one another. As a youth during the English Civil War, he had seen disagreements about the first principles of religious belief and moral conduct shake the foundations of a seemingly stable society. He embarked on an enterprise to search out the foundations of absolute certainty in these things. As he persisted in exploring the problem of certainty and in testing the limits of empirical knowledge, he turned up a wide network of interrelated epistemological and psychological questions. Thus, his transformation from nativist to sense empiricist did not involve only a single change but a slow reorganization of a whole belief system encompassing ideas of cognition, morality, and politics.

Locke relied on a small set of mutually complementary metaphors for knowledge. Some of the more salient ones were as follows: material object, closed space, acquisition, possession, tool or instrument, and wax tablet. This use of metaphor was important because he was able to communicate his ideas in a way that related them to readily recognizable experience. In his writing, Locke made use of his knowledge of commercial, technological, and scientific developments of the time. Was his use of metaphors only communicative, or did they also participate in the actual construction and reconstruction of his thought?

Moore-Russell, in her dissertation, *John Locke on Politics and Cognition: A Case Study of Theoretical Development and Creativity* (1978), asserts that Locke made knowledge objective. In making the idea the object of understanding when the mind thinks, Locke likened knowledge to material objects. The recurrent use of the same metaphorical representations of various aspects of cognition is one of the features of the *Essay* that gives it unity and persuasiveness.

Locke seized on metaphors that occurred to him and examined them for what they could contribute to the problem at hand. For example, the metaphor of the mind as a closed space that contained only its own ideas framed Locke's thinking about the mind and knowledge. It was the metaphor linking ideas and words with objects in motion that permitted him to think about how, given closed minds, apprehension and communication could occur. Each metaphor had a specific role to play in illuminating some aspect of a very broad and complex set of issues. His ensemble of metaphors helped him to think through fundamental questions about human cognition.

*Images of Gender in Dorothy Richardson's Thought*

In her dissertation analyzing Richardson's thirteen-volume novel, *Pilgrimage* (1976), Wallace (1982) shows that Richardson's conceptions of gender were crucial and that they were largely expressed through symbolic language. A group of stable images was used in varying affective climates to express very strong conceptions. Richardson believed that men and women have different natures and that the qualities of their experiences are very different. Her conception of these differences is a major theme in her novel: The image of man centers on the brow (mind) and mouth (body), that of women on a garden. There is a split in men between their minds and bodies; in women there is a different split—between what they really are and what they pretend to be for the sake of men. Women work hard at hiding what they really are; their real selves are secret, beautiful, and connected with nature. Men and women are divided within themselves and from each other. Women are aware of these divisions; men are not. The garden image provides a place where one can experience the joy of existence.

Men are depicted as animals and are seen as dangerous, calculating, secretive, self-important, and deliberately self-segregating. Sentences describing men are full of action verbs like "devour" and "gobble." Through the use of the garden image, Richardson was able to depict what she considered the live center of women and to demonstrate a basically optimistic view of her inner self.

Wallace examines the complexity of this imagistic structure. Richardson is not always hostile to men. Sometimes she sees them as innocent, unaware, and sad. Although the feelings attributed to men may vary, the structure of the image remains the same. This basic image of men as split between mind and body reappears in different situations.

*Metaphor and the Case Study Method*

Our case study work on metaphor brings out certain key ideas. Metaphors do not function in isolation from each other, but in articulated ensembles, each metaphor having its special role in the complex whole constituting the creative work. Each member of an ensemble of metaphors is not so much a sharply defined individual as a family of metaphors, different parts of which become salient at different stages in the development of the work. Members of a family or cluster do approximately the same work, whereas different families play distinct roles in shaping the total configuration of meaning. Both the ensemble of metaphors as a whole and the families of which it is composed evolve through the efforts of the creative person.

It is evident that the development of these ideas about metaphor required the case study method. By using this method, and by focusing on the development of creative works, we have had the advantage of seeing both changes and stability over time and of coordinating the study of metaphor with other developing organizations of knowledge and ideas. What remains to be done is to capture the process of actual generation of metaphors as an individual's thinking progresses.

## THE INTERACTION BETWEEN CREATIVE PERSON AND VARIOUS WORLDS

The concept of interaction provides a key to the generation and comprehension of an expressive text. If every literary work has both expressive and communicative elements, how does the manner of expression enter into communication? In analyzing the structures of these works, we can see the ways in which they are organized to communicate the insights and feelings of the writers. In the process of creation, the creator necessarily monitors the work as it is being produced, and is necessarily the first audience. Studying the communicative and expressive aspects of creative work together is thus inherent in the evolving-systems approach.

### *Life Communicated as Text*

Wallace (1982) studied the development of the writings of Dorothy Richardson, with emphasis on the thirteen-volume novel Pilgrimage. One of the main areas of interest was how the fabric of experience was represented in the texture of the novel. Richardson aimed at writing in a way that life is really experienced—immediately and subjectively. She engaged the reader in the experience, rather than describing it. This she called feminine realism.

The originality of this pioneering example of the stream-of-consciousness genre lay in Richardson's attempt to describe or render the experience from the central character's point of view rather than from an external perspective. This constraint placed certain demands on the writing. For example, it is necessary to depict the passing of time, and with this the developing maturity of the main character. Because the author had chosen not to stand outside her characters' experience, she could not simply tell the reader, from the privileged position of narrator, that time had passed. Instead, she had to convey this through the experience of the main character, Miriam Henderson. Richardson did this in part by her use of sensuous material. She was able to communicate Miriam's increasing maturity by showing that as her experience of the world enlarged, her ways of perceiving and describing it changed.

Because *Pilgrimage* is an autobiographical novel, Wallace could examine the relation between two time frames—that of the novel and that of the real life. Richardson started the novel at the age of thirty-nine and continued it into her seventies. However, the novel covered the ages of seventeen to thirty-nine in the life of Miriam. Thus, Richardson had to present states of lesser development from her vantage point of increased maturity. She had to portray a level of thought different from the level she had currently achieved.

Wallace shows how a life itself becomes transformed in the process of turning it into a novel. She describes different levels at which sensuous experience can be viewed: (1) Sense experiences of the external world. The world is full for Miriam because she knows how to ascribe meaning to the things she senses. Sense descriptions are used to convey her responses and impressions It is important to note that although Richardson is inside Miriam's head in describing the latter's experience, she nevertheless retains authorial control. (2) Sense experience with symbolic implications. Sense experience is symbolized in three different ways: (a) the symbolic meaning is clear to the reader, but not to Miriam; (b) the symbolic meaning is explicitly noted by Miriam and also is clear to the reader; (c) the reasons for the sensations are clear to Miriam, but only gradually become clear to the reader. (3) Sensory experience of fusion with the external world. These are intense occasional experiences in which Miriam reaches another level of awareness and loses her feelings of everyday reality. Richardson was a pioneer in including this kind of experience as a normal occurrence within the framework of the novel. In sum, the complex of sensory experience conveys to the reader much about Miriam: her developing maturity, her sensibility and her "femaleness."

*The Process of Transforming Experience into Poetry*

Jeffrey (1983), in her study of the writing of the long autobiographical poem *The Prelude* by William Wordsworth, also investigated the transformation of experience into literature. She was interested in the means by which experience is recreated in a text. In a preliminary study, she compared the poem *I wandered lonely as a cloud* with Dorothy Wordsworth's journal entry describing the precipitating event, and with a poem by Herrick also dealing with the viewing of a field of daffodils. There are two aspects of Wordsworth's poem that distinguish it from these other writings. One is the extended use of poetic phrasing, meter, and tropes or poetic language. The other is the extrapolation of the experience beyond the event—the giving of extended meaning. This involves a pattern of progressive distancing from the raw event. Not only did Wordsworth recount a moving experience, he also showed the mind at work: perceiving, remembering, and imagining. He described the creative mind as imposing its own order and meaning on sensory data.

The growth of the poem about the daffodils illustrates these points. First, there is a series of transformations: from the initial sensuous experience shared by Wordsworth and his sister Dorothy, to her prose recording of the event, and finally to his retransformation into poetic form. Second, the contents of the poem reveal a process of progressive abstraction from the initial sensuous event to a philosophic reflection on imagination and thought.

*The Prelude* shows Wordsworth's deep interest in psychological questions. Wordsworth described a number of significant memories from childhood, recalling sensory experiences that had special meanings in his mental life.

By reconstructing the order of writing and the pattern and type of revisions in *The Prelude*, Jeffrey concludes that for Wordsworth, writing poetry did not consist of the expression of ideas worked out beforehand, but rather was a process in which new meanings were created and realized. Her findings resemble those of Arnheim (1962) in his analysis of Picasso's *Guernica*: "Picasso did not simply deposit in *Guernica* what he had thought about the world; rather did he further his understanding of the world through the making of *Guernica*" (p. 10).

Jeffrey is particularly concerned with the value and constructive function of repetition (see also Gruber 1976b). She argues that much of the communicative value of the *The Prelude* lies in its repetitive structure. Wordsworth used repetition as a way of deepening and emphasizing the impact of experience. This is essential to the power of the poem. For example, Wordsworth gives ten examples of nature's formative power over him. This repetition allows the revisiting of a scheme, and represents further investigation, enrichment, and intensification. Through her examination of the poet's worksheets, Jeffrey is able to show how Wordsworth built up this resonating structure of reiteration as the poem evolved over half a century of creative work.

## CONCLUSION: THE EVOLVING-SYSTEMS APPROACH TO CREATIVE WORK

Of the many desiderata for a theory of creative work, we have chosen three points for emphasis in this conclusion. First, the distribution of creative work in time; this has clear implications for the motivation and energetics of creative work. Second, the loose coupling of the evolving subsystems of knowledge, purpose, and affect. Third, the need in future efforts to search for and specify nonhomeostatic processes, or *deviation amplifying systems*.

### *Distribution of Creative Work in Time*

Perhaps the single most reliable finding in our studies is that creative work takes a long time. With all due apologies to thunderbolts, creative work is not a matter of milliseconds, minutes, or even hours—but of months, years, and decades. The question then arises: What goes on in this time? Why does it take so long?

Once we give up the notion of mysterious gifts disconnected from knowable psychological processes, it seems reasonable that creative work should take a long time. We call it creative because it is difficult and improbable, new and effective. At the same time, we expect the product to receive a favorable reception in at least some quarters. Such a reception, indeed, becomes one of our criteria for judging the work valuable or effective, rather than merely unusual. But in that case, because the creative product met a felt or almost-felt need, it is reasonable to suppose that others were moving in the same direction, and this is what we often find to be so. That is, others are aware, and more than dimly, that some move in that direction is needed. If, in addition, the move or solution were ready at hand, so that any one of a number of qualified workers in the same vineyard might find it, then it would be a general trend, and we would be unlikely to call it "creative." It is this peculiar combination of improbability and fitness that leads people in situations like Huxley's to exclaim, "How stupid not to have thought of that!"

*Organization of Purpose*

The fact that creative work is difficult and therefore spread out over months and years has consequences for the organization of purpose. In order to make grand goals attainable, the creator must invent and pursue subgoals. Delays, tangents, and false starts are almost inevitable. The creative person must therefore have some approach to managing the work so that these inconclusive moves become fruitful and enriching, and at the same time so that a sense of direction is maintained. Without such a sense of direction, the would-be creator may produce a number of fine strokes, but they will not accumulate toward a great work.

*Initial Sketch*

There probably are numerous tools available for helping to maintain such a sense of direction. An important one is the "initial sketch"—the rough draft or early notebook to which the worker can repair from time to time—that serves as a sort of gyroscope for the oeuvre. The notebooks that Darwin kept in 1837-1838 play such a role—also his *Journal of Researches* (1839), the account of the voyage of the *Beagle*, which is full of examples of his style of scientific thought, but withholds any definitive ideas about evolution. Piaget's poem *The Mission of the Idea* (1916) and his novel *Recherche* (1918c), both written by the age of twenty-two, before he began work as a psychologist, set out—in a rather romantic form—the major lines he was later to follow persistently throughout his life.

But it is a mistake to identify these early sketches with the later achievement. For Wordsworth there was a series of moves, transforming the brief initial sketch, before he could arrive at his great autobiographical poem *The Prelude*. Although Newton had his annus mirabilis (actually two years), it resulted only in initial sketches for achievements that would require the work of the next fifteen-twenty years (Westfall 1980a, 1980b).

On a different time scale, Arnheim (1962) has shown how Picasso, setting out to make the mural *Guernica*, began with an initial sketch that guided the feverish month of activity that produced the work. But the whole point of Arnheim's analysts is to trace and elucidate the transformations the idea underwent and to understand the artistic and ideological motives that steered these changes.

Closely related to the idea of the initial sketch is Maruyama's (1963) idea of the "initial kick." In a system in the early stages of its formation, and therefore still quite labile, the first few moves can be fateful in determining the pathway that will be followed. The first stroke of the brush transforms the canvas.

*Loose Coupling of Knowledge, Purpose, Affect, and Milieu*

In describing the creative person at work, we have found it useful to conceive of the person as a system of three main interacting subsystems: knowledge, purpose, and affect. The fact that they interact is not taken to mean that the state of any one subsystem can be inferred from knowledge of the others. Each has its own independent mode of functioning and its own history. They are only loosely coupled. This provides a prime way for the introduction of some probabilistic aspect into our way of thinking about creative work without being mystified into surrendering the whole to chance. Even if each subsystem were highly deterministic in its mode of operation, which is, of course, not the case, the system as a whole would be nondeterministic because of the partial independence of the subsystems.

To see how these subsystems might work together, let us consider only one hypothetical example. Let us suppose that a creative person at work is baffled by a task, discouraged, and inclined to put it aside. Fortunately, his activity level does not go to zero, because other enterprises are liberated and activated by the very process of stopping work on one project. Fortunately, too, his discouragement and motivational reorganization does not destroy all the knowledge and skill he has acquired relating to the project in question; when his mood shifts or a new opening for further progress on the fallow project presents itself, he does not begin at zero, but takes up more or less where he left off. Serendipitous experiences, such as Darwin's critical encounter with Malthus's *Essay on Population* (1826), happen to a prepared mind precisely because these organizations of knowledge, purpose, and affect are both enduring and loosely coupled.

All this internal movement takes place within the mind of an individual who is also engaged in rich and complex interactions with his external milieu, both in its social and physical aspects. This milieu is not handed to the person or imposed from without; it is something that the individual plays a part in choosing and constructing. A good example of this is the complex set of relationships among William Wordsworth, Samuel Coleridge, Dorothy Wordsworth, and the world of nature that Wordsworth wrote about so beautifully. William's *I wandered lonely as a cloud* could not have been written without the celebrated walk in the field of daffodils, or without Dorothy's wonderful notes about the same walk, or without the philosophy of nature that the two poets worked out together—which entailed also Coleridge being steeped in German *Naturphilosophie*.

*Nonhomeostatic Processes*

Let us suppose that creative work is almost invariably organized into a set of tasks and subtasks, with some degree of hierarchical structuring. It is important for the creative person that work be so organized that success along the way does not lead so much to a sense of satisfaction as to a sense of liberation—to do whatever comes next. Westfall (1980b) called his excellent biography of Newton *Never at Rest* to capture just this point. There may be many different configurations of a complex network of enterprise, with its manifold relations with other subsystems in the creative mind, that are capable of generating this consequence that achievement becomes the spur for further achievement. Too much emphasis can be given to the role of extrinsic motivation ("Fame is the spur ..."). Amabile's book *The Social Psychology of Creativity* (1983) is particularly important in placing the emphasis on intrinsic or task-oriented motivation in creative work. This idea, coupled with attention to the structure of the network of enterprise, is probably what we need in order to understand the seemingly perpetual activity of the creative person.

Besides having an organization of purpose represented by a network of enterprise, there are other conditions that must be satisfied if the creative person is to be kept in goal-directed motion. The most important of these is the perfecting of some heuristics that recognize, preserve, and elaborate embryonic novelties. There probably is an unlimited variety of such "deviation amplifying systems" (Maruyama 1963) available for the inventing, and any given individual probably can manage only a small number of them—but that may be all that is necessary. This is a subject urgently requiring further research.

One simple example of a deviation amplifying system is the repetition of interesting acts or the revisiting of interesting sites. Variations inevitably occur; the creative person does not suppress them, but builds on them, finds ways of pushing them to their limits. In an earlier study, building on Lewin (1935) and Piaget (1952c), who in different ways had written on this subject, Gruber (1976b) described the constructive function of repetition (see page 195). In the person committed to a line of work, the simple act of constructing a filing system or other mechanism for bringing similar cases together also has the consequence of permitting the deviations to appear and the person to seize on them. When Darwin was having his early love affair with the idea of variation, he came home one day enthralled with the fact that there were, in one London garden, "1,279 varieties of roses!!!"

# Networks of Enterprise in Creative Scientific Work

In many discussions of creativity, so much emphasis is put on such features as spontaneity, intuition, and unconscious processes that one loses sight of the fact that, for the most part, creative work is purposeful. Even the less rational features of the entire process take place within a context regulated by the creative person's purposes. In the *evolving systems approach to creative work* (Gruber 1980b; Gruber and Davis 1988; Wallace 1985; Wallace and Gruber 1989), we have considered the creative person as a system composed of three main subsystems: an organization of knowledge, an organization of purpose, and an organization of affect. Each of these subsystems is constantly evolving, and is doing so in a sort of internal milieu provided by the others.

One important feature of the evolving systems approach is the embodiment of the organization of purpose in networks of enterprise. I use the term "enterprise" to cover groups of activities extended in time and embracing other activities such as projects, problems, and tasks. Commitment to an enterprise is exhibited by the recurrent reappearance of activities belonging to it. The key point is that the creative completion of a project leads not only to satisfaction and relaxation but also to the replenishment of the stock of projects and problems within the enterprise in question, and to reinvigoration for further work.

The concept of enterprise helps us to understand the organization of a creative person's activity. The day-by-day pattern of activities sometimes looks quite chaotic, but when we understand how each act is mapped onto some enterprise, it takes on a more orderly form.

Enterprises rarely if ever occur singly in a creative scientific life. In some cases (such as Darwin and Piaget, who will be used as case material below) we see very complex networks of enterprise. The examination of such patterns of commitment provides a way of understanding the motivational dynamics of the creative person without appealing primarily to forces unrelated to his or her actual work.

A fundamental part of any psychology of science must be a theory of the motivation of scientific work. To a very large extent, important and innovative scientific achievements are the result of protracted hard and unremitting work. Motivational factors can be divided into two main kinds: intrinsic and extrinsic. Correspondingly, theories of motivation differ in the relative emphasis they put on these two kinds of motive forces. In her book, *The Social Psychology of Creativity* (1983), Amabile has given a good up-to-date account of research on intrinsic motivation and has described her own program of research on its role in creative work. In the present essay, although I explore various kinds of theories, the emphasis is upon intrinsic motivation. In this concern I join with earlier ideas, especially Allport's idea of functional

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autonomy (1937) and Lewin's idea of task-generated tension systems (1935). If there is anything theoretically new in my approach to the question of intrinsic motivation, it is the insistence on looking at the creative person's entire pattern of intentions, his or her network of enterprise.

Some writers have stressed the importance of such extrinsic social factors as group pressures and paradigmatic fashions. Others have stressed the kind of personal psychodynamics, largely unconscious, that are central in psychoanalytic theory. By no means do I doubt or deny the importance of such extrinsic motives. They must certainly be included in any complete theory of the motivation of scientific work. But I do not believe that lifelong patterns of steady devotion to hard work, and commitment to remote goals, can be explained by exclusive recourse to such extrinsic factors. It is to the demands of the work itself, the fascination with it, the intention to do it, and the far-off vision of the creative product that we must look first for the explanation of lifelong creative effort.

## SCIENCE AS WORK

Work is human activity organized so that it leads to productive ends. Both the nature of the activity and the nature of the end products are usually agreed upon by some social group. It is usually presumed that the product will be in some sense socially useful. The whole process is usually organized in such a fashion that the cost, timing, and use of the product are all at least moderately predictable. Because the primary goal is production, repetition of known and reliable processes plays a prominent role. Innovation is kept to a minimum because it is often disruptive and unpredictable.

Scientific work is, in principle, peculiar. Its product is often highly unpredictable both as to kind and as to timing. Even when the scientific value of a specific "product" is very clear and unanimously agreed upon by the cognoscenti, its social value may be unclear to everyone—except, of course, for some general faith in the value of science. Furthermore, science continually transforms itself. This is reflected in Newton's remark in a letter to Robert Hooke on February 5, 1676, "If I have seen further it is because I stood on the shoulders of giants." There is a premium on novelty, and sanctions against repetition. A New York dress designer can survive by copying the latest designs from Paris. This is not possible in science, except in the limited sense of replication for purposes of testing reproducibility of findings. Insofar as science is discovery, we do not set out to discover what others have already found. Paul Tillich said somewhere, "The scientist loves both the truth he discovers and himself insofar as he discovers it."

## WORK AND REVOLUTION

Although he did not call it an essay on work, in *The Structure of Scientific Revolutions* (1962), Kuhn explored the relationship between the steady work of "normal science" and the revolutionary crises that result from such work. His account was meant to be transhistorical, applying to science in all ages. It is important, however, to examine the nature of work in a more historical light.

The idea of scientific creativity as "purposeful work" suggests immediately the connection between the rise of capitalism, the Protestant Reformation, and the scientific and industrial revolutions—all of which happened close enough together in time to form an interesting group. The Protestant idea, "Every man his own priest," may seem, to a modern person, just the kind of religion, if any, an independent, creative scientist would need.

This picture of science as somehow clothed in the Protestant garb of individualism and the work ethic was reflected in a symposium on creativity in McClelland's essay (Gruber, Terrell, and Wertheimer 1962) on the motivation of scientists. McClelland's work on the "need for achievement" was an effort to translate into specifically psychological terms the line of thought expounded by Max Weber in his classic *The Protestant Ethic and the Spirit of Capitalism* (1930). Among the personal virtues esteemed in that ethic are a powerful devotion to a calling, hard work, individualism, and asceticism. If in some instances the devoted hard work and asceticism led to some savings, the asceticism prevented extravagances of wealth that might be permissible in other milieus. Where, then, could the profits be put? "One of the few things one could in good conscience do with savings was to plow them back into the firm, or more modestly, open a shop of one's own" (Brown 1965). In other words, this ethic provided the ideal psychological base for behavior that would contribute to a steadily expanding economy.

In a major work, *The Achieving Society*, McClelland (1961) argued that this idea could be applied across history and across cultures. In some studies he used projective tests to measure need for achievement, in others he used content analysis of folk tales or of stories for children. Need for achievement correlated positively with various indices of economic growth. Because his work went well beyond the limits of the Christian world, McClelland revised the original thesis to suggest that many religions have within them sects that might foster the necessary psychological qualities for high achievement motivation.

McClelland (1962) made an explicit attempt to apply the same line of thought to scientific achievement. To simplify his task somewhat, he took as his task the explanation of the motivational dynamics of physical scientists. Reviewing previous literature, he drew the following conclusions:

1. Men are more likely to be creative scientists than women.
2. Experimental physical scientists come from a background of radical Protestantism more often than would be expected by chance, but are not themselves religious ...

3. Scientists avoid interpersonal contact ...
4. Creative scientists are unusually hardworking to the extent of appearing almost obsessed with their work ...
5. Scientists avoid and are disturbed by complex human emotions, perhaps particularly interpersonal aggression ...
6. Physical scientists like music and dislike art and poetry ...
7. Physical scientists are intensely masculine ...
8. Physical scientists develop a strong interest in analysis, in the structure of things, early in life. (pp. 144-150)

I do not propose to evaluate all these conclusions here. The reader should be warned that they come from studies of quite diverse populations, ranging from fairly large-scale studies of research scientists in industrial settings to small-scale studies of very eminent scientists, to studies of university science students. McClelland went on from this empirical base to a psychoanalytically oriented hypothesis, proposing a particular version of the Oedipus complex typical of young boy future scientists. From this, McClelland and his student, Greenberger, deduced—through a line of reasoning that the former himself admits is "tortuous"—that scientists "would prefer metaphors describing nature in positive feminine terms, thus revealing that their life-long intense concern with nature might at its root derive from its female connotations, from its capacity to serve in some way as a mother substitute in fantasy" (McClelland 1962, 158).

The test of the hypothesis that science is a mother-substitute was conducted by giving the subjects fifty-nine metaphorical descriptions of nature to rate, as to how well they describe nature. Science-oriented subjects differed in their ratings from non-science-oriented subjects. Among the metaphors most preferred by scientists were "a pillar of strength and virility," "a perfect woman nobly planned," "a grand and inspiring father," and "a banquet of delights." Among those least preferred by scientists were "the desolation of many generations," "a tyrant despite her lovely face," and "a great cave that encompasses us and swallows us up like atoms." McClelland concluded that "there is little or no support for the hypothesis ... that nature represents for scientists either a sexualized or pre-Oedipal mother image" (p. 161). But putting all his new data together with some of the old, he adduced a new hypothesis, "that scientists work so hard and love their work so much to satisfy not sexual but aggressive needs" (McClelland 1962, 166). He was cautious in advancing this hypothesis and gave only some very tentative evidence for it.

It seems to me that this episode in McClelland's fruitful career went astray because of its reliance on an idea that was simple, but not simple enough. The formulaic notion was that the Protestant ethic leads to hard work and asceticism, that these qualities are necessary for scientific success, and that therefore to explain scientific success we must find a psychodynamic explanation for those qualities.

An even simpler idea is the following: If someone, for example, Charles Darwin, becomes fascinated by science, the work itself draws him on; if he works hard, it is because the task is hard and he is engrossed in it. If he withdraws from other pursuits, keeps his distance from people (or better, from some people), again it is because he is engrossed in his work. If he seems ascetic, it is because no jewel is more beautiful than the atom, no luxury cruise more fascinating than a voyage of discovery. This simple idea of task involvement provides the basis for understanding the organization of purpose of the working scientist. It does not, of course, explain how he or she gets that way. My thesis, to be developed below, is that it is a mistake to look for a single explanation of the psychosocial origins of scientists. Science is such a manifold set of activities; its social status and function change from one quarter-century or generation to another, and from culture to culture. There is room and need in it for different personalities, cognitive styles, and life-styles.

There is something wrong with the strategy of treating individuals as though they were faithful mirrors of the institutional and cultural frameworks within which they work. Catholic scientists are cases in point. Copernicus was a priest. Although he found himself in conflict with the Catholic Church, it was within the milieu provided by that institution that he did his work. Galileo, whose conflict with the Church was protracted, nevertheless flourished in a Catholic country. Mendel was a priest. Although the science of genetics itself might seem, in historical retrospect, to have been protected from theological criticism, Mendel himself, however, believed that his work would contribute to understanding the "transformation of one species into another" (p. 357) and more generally that he was investigating "a question the importance of which cannot be overestimated in connection with the history of the evolution of organic forms" (Mendel 1909, 318).

Because the stability of the gene seemed to contain intimations both of immutability and immortality, early genetics (ca. 1900) was taken in some quarters (see Eiseley 1958, 204-253) both as an answer to Darwinism and as a support of religious faith. Modern genetics plays no such roles—which all goes to show how foolish and ephemeral it is to treat scientific work as though it was simplistically motivated by religious or other ideologies.

Consider two scientists, both Jewish, who did rather similar work—John von Neumann and Norbert Wiener. One was conservative and well-organized, the other radical and messy. Neither was particularly ascetic. Probably the only quality they had in common was working hard (Heims 1980).

The emphasis on hard work in the Weberian way of thought is echoed in Kuhn's descriptions of normal science. Revolutionary science, for all we know of the difference between the two, may display quite other patterns of work. In wars and revolutions people probably do not do such steady work. They lie about and agonize about what to do, they "hurry up and wait" (old army phrase), and then they get caught up in desperate episodes of frenzied activity. All that is not quite what Weber meant.

If it is hard to generalize about "normal" science, we might expect even greater difficulty with the irregularities of revolutionary science. Still, it is tempting to expect that individuals free of commitments to establishments of religion and politics would be predisposed to make great scientific advances, supportive instances come immediately to mind: Darwin was an agnostic; Einstein was a pacifist, etc. But negative instances are prominent, too: for example, Mendel and Newton.

It seems to me that we can rescue at least something of the notion that creative scientists are nonconformists. Evidence such as Crutchfield (1962) is important. Using a group-pressures technique adapted from Asch's work (1952), he was able to show that when obvious truths were pitted against a contrived group consensus, research scientists held out against the consensus better than did unselected college students; among men, military officers were the most yielding to group pressures. Still, in every group tested, there were some subjects who never yielded, and the average conformity score within a group never rose above 38 percent.

It is at least possible that the study of science does cultivate an individualistic spirit, at least where judgment of matters physical, such as line lengths, is involved, as in the Asch experiments. Perrin and Spencer (1981) conducted a quite exact replication of Asch's experiment with a group of British university students. In this group they found *zero* conformity behavior! The authors suggest that their result can be explained by historical differences; chiefly that Asch's American subjects were tested during the McCarthy Period, when many people in our unfortunate country were keeping their heads down. This may well be the correct explanation. The fact remains, though, that Perrin and Spencer's subjects were all students of engineering, chemistry, and physics.

Perhaps more important is the simple argument that the knowing innovator must be prepared for the disruption and conflict attendant on novelty. In general, scientific discoveries do not happen to just anyone, but to those who fully intend to do science. In other words, they conduct their lives under the aegis of a general intention to make a change in the condition of human knowledge and thought. But this does not mean that scientists must be rebels. Within their fields, if they want to innovate, they must eventually confront tradition. This may, but need not, be associated with a generalized radical attitude.

Perhaps, too, we have been asking the wrong question. Instead of asking whether or not, or how much conformity a subject or group exhibits, we might ask, how does this person cope with situations in which there are pressures to conform? This approach would, I believe, be in accord with Asch's own way of thinking. A little reflection shows that there are many ways of dealing with the problem of social pressure without surrendering one's goals or ideas. As we shall see below, the development and management of the network of enterprise plays a role in the way individuals cope with social pressures.

All told, the very pluralism required of the organization of the creative mind (see below) suggests that no simple generalization about the motives governing scientific work will obtain, and the facts certainly bear this out. Our interest in the idea that creativity is purposeful work has led us to the above examination of certain rather broad psychosocial-historical generalizations about the nature of mental life when it is organized as work. As we have seen, plausible and valid generalizations are hard to come by. In my view, the efforts have been pitched at too abstract a level. We do not have a clear and concrete picture of what the scientist actually does when he or she works, and so we are not clear about what it is we are trying to explain.

## THE ORGANIZATION OF CREATIVE WORK

Work involves human activity organized in time. The fact that it is organized sequentially is one of its most prominent features. The hunter must make a trap, then set it; catch the prey, then butcher it; cook it, then eat and share it—all in the order given. Likewise, the scientist must make equipment, then set it up: collect data, then analyze it; draw conclusions, then reflect upon them and disseminate them.

In recent years, especially in advancing toward artificial intelligence, there has been a great deal of emphasis on the hierarchical organization of behavior including the acts we call cognition. Inherent in Miller, Galanter, and Pribram's (1960) concept of the "plan" were the ideas of sequential and hierarchical organization. In another vocabulary, in their treatment of scripts, plans, and goals, Schank and Abelson (1977) had the same point in mind: There are certain molar units of behavior that are stably organized and repeatable out of which larger and more complex units can be produced. The person has means of detecting when a lower-order unit has been accomplished, so that he can go on either to repeat it or to the next part of the plan. In his essay, *The Architecture of Complexity*, Simon (1969) explored the same issue of organized complexity. His parable of the two watchmakers is designed to emphasize the necessity of organizing work hierarchically so that subunits can be produced that are stable enough to withstand interruption or other vicissitudes. This is especially important for complex and protracted tasks where aspects of the worker's life outside the ambit of the task in hand are likely to impinge on the process of work.

Lewin (1935) proposed that undertaking a task produces a tension system that serves as a motivating force to organize behavior for the completion of the task: The person remembers the unfinished task; perception of the environment is transformed by the tension system so that the world is seen in ways relevant to the task; and when opportunity arises, he or she chooses to complete the task rather than to do something else. Lewin and his co-workers and later investigators conducted various experiments intended to substantiate this hypothesis. On balance, it holds up pretty well. But in the laboratory, task tension systems are probably somewhat more fragile and evanescent than Lewin's theory suggested. And why not? The tasks Lewin et al. gave their subjects, whether interrupted or not, were themselves interruptions of the flow of life that each subject enjoyed outside the laboratory! The small forces induced in the laboratory must contend against the much stronger and longer-lived motivations, goals, and intentions of normal life.

The idea of network of enterprise can be applied to the working lives of scientists in a way that elaborates Lewin's basic line of thought. This simple idea, that work must be organized so that it can be interrupted and then resumed, has important consequences for understanding scientific creativity. From our examination of the working lives of scientists, we discern certain major features of the organization of work. It should be emphasized that each of these is a sort of parameter; its exact value is set by the person in the course of organizing a life, constructing a career. The examples I will use illustrate the following:

1. Longevity of most enterprises
2. Distinctions among enterprise, project, and problem
3. Branching tendency of enterprises
4. Both hierarchical and heterarchical features of the network of enterprise
5. Communication among enterprises
6. Importance of early moves in formation of the network of enterprise
7. Influence of social factors in shaping the organization of purpose
8. Relation between the evolving organization of purpose and the self

## SOME OBSERVATIONS ON CHARLES DARWIN'S NETWORK OF ENTERPRISE

One example from our knowledge of the development of Darwin's organization of purpose will serve to suggest how powerful and stable an organizing force of an unfinished task can be on the scale of the life history.

In 1837, at a meeting of the London Geological Society, Charles Darwin read a paper, *On the Formation of the Superficial Layer of Earth, Commonly Called Vegetable Mould* by the digestive process of earthworms (Darwin 1837b). From Darwin's remarks and from its position in the sequence of Darwin's work—immediately after a paper on the way the tiny coral organism makes coral reefs (Darwin 1837a)—it is clear that he was expressing an underlying interest in the way organisms make and remake the earth. This was important, but not central to his work on the theory of evolution, then in full flood. He put the worm work aside for awhile and later wrote in his Autobiography, "I have now (May 1, 1881) sent to the printers the MS of a little book on [worms] ... It is the completion of a short paper read before the Geological Society more than forty years ago, and has revived old geological thoughts" (Darwin 1958, 136).

The incident illustrates not only the longevity of an enterprise but its power to organize behavior and its tendency to branch. On the first point, a full reading of the Darwin manuscripts shows that he worked on the worm project from time to time throughout the long interval, that he conducted various ingenious experiments, and that he drew on informants, both nearby neighbors and scientists all over the world. One of his sons with engineering talent built the "Wormstone"—a machine in the Darwin's garden for measuring the gradual burial of a stone by the castings of worms. On the second point, branching, the full title of the eventual book tells the story: *The Formation of Vegetable Mould Through the Action of Worms, with Observations on Their Habits* (1881). The geological project had developed a behavioral branch! The book carries out its original geological theme, but it is also a pioneering study of invertebrate animal behavior (see Gruber, 1981e).

As with all evolving organizations, the network of enterprise entails some problems in classification. Looking at Darwin's worm work as a project, we can say that it developed a behavioral branch. Looking at Darwin's network of enterprise as a whole, we can say that aspects of the same project can be mapped onto more than one enterprise. One of those enterprises was the study of the evolution of intelligent behavior: one branch of that enterprise paid special attention to "lower" organisms. The worm project found its place there.

In Darwin's case there is an intimate relationship, one that colored almost his entire working life, between the shaping of his network of enterprise and the ways he dealt with potential conformity pressures. I have described elsewhere (Gruber 1981e) in some detail how Darwin carried out two great delays:

First he avoided publishing his ideas on evolution for some twenty years; then he waited another twelve years before publishing his ideas on Homo sapiens' place in the evolutionary scheme. Thus, to avoid exposing himself to conformity pressures before he was good and ready, he was able to keep silent for a long time. He also moderated the presentation of some of his ideas, or "truckled" as he once ruefully put it, especially where religious sensibilities might be offended. He also managed his network of enterprise in ways that would strengthen his status as a scientist, which helped him to withstand the attacks that were to come; this last was especially true of his eight-year study of barnacles—after he had worked out the theory of evolution pretty thoroughly and before he wrote the *Origin of Species*. This was a good move: He produced a four-volume series on barnacles, the classic work on an important group of organisms; he gained time to work out his ideas even more fully and to convince or half-convince some potential allies; and he certainly gained status as a systematic scientist. The barnacle enterprise had its beginnings during the Beagle voyage, or even earlier. The decision to activate it and to put the evolution enterprise on hold was one constructive way to deal with conformity pressures.

Darwin was at many points acutely aware of his evolving organization of purpose. Indications of his planning crop up repeatedly in his letters and other documents (see Darwin 1934). Too much has been made of the seemingly accidental way in which he became the Beagle's naturalist. True, others were asked before him, and his opportunity depended on their refusals. On the other hand, he had already been planning a scientific expedition to Tenerife; he had begun recruiting collaborators, explored the availability of ships, and studied Spanish (Barlow 1967). His motives for choosing Tenerife are not clear, but in fact it was an interesting choice, having flora and fauna that are distinct and yet related to a nearby continent, and being part of an archipelago.

During the voyage there were many instances of planning, both with regard to his work during the voyage and his goals for later on. On December 13,1831, on board the *H.M.S. Beagle* but still in harbor at Devonport, he made a list of his tasks for the voyage, mainly in natural history but also to develop himself as a cultivated person.

On January 17, 1832, in the Cape Verde Islands, he wrote in his Diary of his

> first burst of admiration at seeing Corals growing on their native rock. Often whilst at Edinburgh have I gazed at the little pools of water left by the tide: & from the minute corals of our own shore pictured to myself those of larger growth: little did I think how exquisite their beauty is & still less did I expect my hopes of seeing them would ever be realized. (Darwin 1934, 25)

Three years later, still on board the *Beagle*, he was to work out his theory of the formation of coral reefs. In its formal structure, that theory was much like his theory of evolution. So we have in this early passage an indication of Darwin forming the interests and acquiring the apperceptive mass for an important enterprise.

On February 28, 1832, in Brazil, he wrote a rapturous entry in his Diary, describing his first reactions to the glories of a tropical forest, concluding, "The mind is a chaos of delight, out of which a world of future & more quiet pleasure will arise" (Darwin 1934, 33). This theme, the anticipated contrast between present adventure and later tranquility, is mentioned repeatedly in the Diary.

Planning requires a choice of time scale. Darwin was no stranger to this issue, since it figured so prominently in his geological work (Rudwick 1982). He also thought about it on the scale of personal history. For example, on August 29, 1832, cruising off Monte Video, he wrote of the psychology of time, "[T]he clearness with which I recollect the most minute particulars, gives to the period of an year the appearance of far shorter duration. But if I pause & in my mind pass from month to month, the time grows proportional to the many things which have happened in it" (Darwin 1934).

As the voyage wore on, Darwin's goals for that period grew more settled, and accordingly he wrote less about them. It should be added, of course, that his planning had always to be general and flexible, as he continually adapted himself to opportunities and exigencies imposed by the realities of a naval voyage. Toward the end of the five-year circumnavigation, his letters to his mentor, the botanist Professor John Henslow, give a good picture of Darwin's network of enterprise and of his anticipation of the work to be done in processing the collections he has made in many branches of natural history. He had some awareness of the realities of professional life. On July 9, 1836, writing from St. Helena, he asked Henslow to nominate him for membership in the London Geological Society. This reflects his primary activity during the voyage, which was in the field of geology (see Gruber and Gruber 1962; Sulloway 1996).

In 1838, shortly before proposing to Emma Wedgwood, he wrote several pages of "marriage notes," listing and reflecting on the various advantages of marrying and those of not marrying, concluding "MARRY—MARRY—MARRY QED." (Darwin 1958; see also Keegan and Gruber 1983). The central point in these notes was really his career plans with various enterprises specified, and the ways in which they could be pursued if he did or did not take the fateful step. He did take it, he enjoyed the benefits of a "nice soft wife on a sofa with good fire," and a country life conducive to long years of reflection, with room for his many experiments. He planned his life and lived it the way he planned it. Among the projects he mentioned were "transmission of Species—microscope—simplest forms of life—Geology? Oldest formations?? Some experiments—physiological observations on lower animals." And in thinking about where to live with the woman in question he wrote:

> I have so much more pleasure in direct observation, that I could not go on as Lyell does, correcting and adding up new information to old train, and I do not see what line can be followed by man tied down to London.—In country—experiment and observations on lower animals,—more space. (Darwin 1958, 231-232)

## THE EVOLUTION OF JEAN PIAGET'S NETWORK OF ENTERPRISES

Jean Piaget began his lifelong studies of molluscs in adolescence. Working in the mountains and lakes of Switzerland he became a well-known expert in malacology, publishing his first paper in that field at the age of thirteen. In the same field, by the time he was eighteen, he had published thirty papers and went on to write his doctoral dissertation in 1921. He continued to work in that field all his life, although other interests occupied more of his attention (Piaget 1976a).

At about the age of fifteen, he had done enough to earn the right to worry about the meaning of science and its relation to philosophy and religion. In 1915, at the age of nineteen, he wrote a long prose poem, *La Mission de l'Idée*, which was a romantic evocation of liberal Christian theology, youthful suffering about the meaning of life, concern about the First World War, and hopes for a pure and principled life when the war ended. These themes were further explored in a philosophical novel, *Recherche* (1918c). In both of these works he appears as an outspoken Christian Socialist. He went on to write two treatises during the 1920s on ethical and theological questions (Piaget 1928, 1930).

This was the decade in which he was becoming a psychologist, and by 1932 he had transformed his religious concerns into a pioneering and still influential scientific study, embodied in his somewhat Rousseauvian book, *The Moral Judgment of the Child* (1932). For all practical purposes, that was the last of his writing on the subjects of theology and morality, although in the 1940s he did touch on certain ethical issues in several sociological essays (Piaget 1965).

Bringing an enterprise to a close is unusual enough to warrant some attention. Vidal (1987, 1989) has shown how Piaget was always sensitive to his social milieus. When he wrote his early theological poem and papers, he was writing for and as a prominent member of the Christian youth movement. When he reduced his concerns with moral philosophy and moved decisively toward preoccupation with epistemological issues, he was under some political pressure to do so. This was the period of the Great Depression and worldwide social dislocations. In Switzerland there were reactionary responses to the revolutionary impulses of the period. In pacific Geneva, there was a night of demonstrations on November 9, 1932, in which the army killed ten people and wounded sixty-five others. Conservative and protofascist social forces, panicky over the prospect of revolution, attacked Marx and Rousseau, pacifism, liberalism, socialism, and democracy in education. One form this struggle took was pressure on the *Institut Jean Jacques Rousseau* to avoid anything that might smack of the expression of antiauthoritarian ideas, even in the veiled forms it might take as psychological research.

At the time, Piaget was assistant director of the *Institut Jean Jacques Rousseau*. The university status and the budget of the Institut were threatened, and it fell to Piaget to draft the response to one of the important political attacks on it. In this letter, signed by the director, Pierre Bovet, assurances were given that "political questions are entirely foreign to our activity." Vidal concludes his account of this episode:

> The Rousseau Institut was not devoted to politics but it was animated by a social project for international understanding and peace: the promoters of the "école nouvelle" and the "école active" were inspired by ideals of democracy and liberalism ... The founding fathers [of the lnstitut] had to give way to their more "realistic" collaborators, capable of suppressing moral concerns in an increasingly "neutral" and "scientific" organization of psychological research. (Vidal 1987)

To be sure, like everyone else, Piaget was not immune to the political pressures of his time, and had to find ways to survive as an academic under changing circumstances. But it should be emphasized that his move toward epistemology had begun early in the novel *Recherche*. As I see it, for Piaget devotion to the priesthood of science was the coherent way to satisfy the claims of conscience and of intellect. In his youthful writings, moral-political concerns were fused with scientific ones; in the 1930s a separation was effected and a sharp change in emphasis occurred, with only the epistemological-mathematical side of his work continuing to develop.

It should be added that Piaget found a wider platform to express his interest in the betterment and renewal of education. Beginning in 1933, he was for many years the director of the *International Bureau of Education* (along with his various professorships in history of science, sociology, psychology, etc.). As Gruber and Vonèche (1977) have pointed out, Piaget did not actually advance a particular education program. Instead, he presided over an evolving field in which many "Piagetian" educational experiments were and are still being carried out.

By this time the reader may be wondering, am I reading about the same Jean Piaget who is famous for his research on children's thinking with special interest in the discovery of formal structures underlying intellectual development? Yes, and yes but. To sum up thus far: Piaget's early highly descriptive work with molluscs led him to a philosophical crisis. This entailed deep concerns about the relation between science and faith—the central theme of *Recherche*. This theme, or its derivative, then found expression in his psychological research on moral development. Meanwhile, Piaget's philosophical concerns led him deeper and deeper into the study of children's thinking, logic, and epistemology. Beginning in 1919, he studied psychology in Zürich and Paris, then received a series of academic appointments in Switzerland

and began the flood of psychological and epistemological writings most closely associated with his name. In short, he had a complex network of enterprises in which new ones emerged while old ones were still active, and the whole continued to grow in complexity up to some rather wide limit.

In general, he did not drop enterprises but managed somehow to keep them going. His wide interests did not stem from simple wide-eyed curiosity but from a deep commitment to the unification of knowledge. Obviously, this whole set of enterprises could not be conducted as a one-man band. Throughout his life Piaget found collaborators who helped him in various ways. This style of working with others found its ultimate expression in the *Centre International d'Epistémologie Génétique*, which he founded in 1955 and which continued for some years after his death. At the Centre, people came together from various disciplines—philosophy and all the major branches of science. The series of monographs published by the Centre were never translated and are not widely known today.

Piaget's work with children came to center very heavily on logical, physical, and mathematical thought. Coupled with his own writings on logic and epistemology, this makes one very important group of projects. But Piaget began as a biologist and remained one all his life. One of his last books was *Le Comportement, Moteur de l'Evolution* (1976b). This was by no means an afterthought but one of a series of important biological works, mostly theoretical but including one botanical monograph (Piaget 1966d) among his later writings.

Piaget's goal was a genetic epistemology that would take full account of the biological nature of intelligence (Piaget 1966c, 1971). The biological work is distinct from the other work in that there was very little research on children's thinking about biological phenomena. In other domains Piaget used his studies of children's thinking on specific topics to help him in his own reflections on related epistemological questions. It is reasonable, therefore to separate off his biological work as representing a separate cluster, so long as we bear in mind his deep commitment to the unity of knowledge. Indeed, this interest in the unity of knowledge and in the importance of interdisciplinary relations became itself one of his enterprises. For others it might be a theme to be mentioned from time to time. Piaget began writing on the subject in the novel *Recherche*, where he first proposed his idea of the "circle of the sciences" and later produced a number of monographs on the subject. Moreover, the three-volume *Introduction a l' Epistemologie Génétique* (1950a) is both a casting up of accounts at the time it was written and an expression of this passion for the interconnectedness of all knowledge.

Thus, Piaget's network of enterprise has the peculiar characteristic that one of the enterprises is a prolonged reflection on the relations among all of them. He sought a coherent way of structuring the relations among the sciences. The image of the circle of the sciences plays a dual role. On the one hand it is meant as a criticism of and substitute for Comte's linear ordering of the sciences (from mathematics on top to sociology on bottom). On the other hand, it expresses the idea of complementarity among the branches: Each discipline makes assumptions that it cannot justify within its own terms of reference. These necessary presuppositions are the warranted conclusions of a neighboring discipline. Thus, although no discipline is closed and stable within itself, the whole stands firm.

Although Piaget reiterated this idea of complementarity throughout his life, another idea, parallel structures, became more prominent later on. By "parallel structures" I mean simply the recognition that formally similar or corresponding groups of ideas can be found in different disciplines or in different cultural-historical contexts. Although it may not have been his original intent, the *Centre International d'Epistémologie Génétique* became, for awhile at least, a Genevan expression of the Structuralist movement (Piaget 1970b). His essay, *Main Trends in Interdisciplinary Research* (1973c) expresses both ideas, but the emphasis is heavily on the value of the search for parallel structures; at the time, he saw this as one of the special merits of the "new branch of science," genetic epistemology.

The particular genetic version of the fusion between epistemology and psychology that Piaget created and propagated has at present produced only a smouldering fire among American psychologists. Nevertheless, the general idea of such a fusion is reflected in the currently vigorous "cognitive science" movement (see De Mey (1982) for an excellent account by a sociologist, and Gardner (1985) for a psychologist's version).

Piaget's case is valuable in exemplifying several concepts that are important for understanding the development of an organization of purpose. First, we see an *early cathexis* with a particular domain, in his case a branch of natural history, leading to an organized set of activities that served as an important training ground. Second, we see him adopting a few *personal models*, so that his own early pattern of work borrowed from certain teachers. Third, we see the *branching growth* of his network of enterprises. Fourth, we see at least two attempts at an *initial sketch*; I refer to the way in which so many of the themes that later came to occupy his mature attention were expressed in *Mission* and in *Recherche*. Fifth, we see that, with one important exception, his enterprises displayed the same *longevity* that we are now accustomed to expect. Even the exception (the religious-moral domain) lasted at least seventeen years.

Finally, we see that, even though almost all of Piaget's activities, taken separately, fall under reasonably conventional disciplinary and institutional rubrics, the pattern as a whole was unique. Moreover, some of the institutional arrangements were of his own contriving. Thus, while Piaget was in many ways responsive to his intellectual and social milieu, he also helped to create it.

Perhaps most important of all, we can see how the network of enterprise became a driving force that guaranteed that he would work incessantly. Each enterprise had its own intricacies so that solving some problems opened new ones. Each enterprise was linked to the others so that progress on one front stimulated work on others. The embodiment of the network of enterprises in a social network guaranteed that every bit of work would stimulate others, who would in turn stimulate him, keeping the network vibrating, like a spider's web with every new catch.

## CONCLUSION

A striking feature in the career of a number of scientists is the effort to study widely disparate phenomena and, wherever possible, to establish conceptual links among them. Newton aimed at applying the same principles to the movement of the planets and to terrestrial mechanisms. As a young man in his *annus mirabilis* (actually two years), he began the quest for the mathematics that could link the almost infinite with the infinitesimal, which he eventually applied in the domains of astronomy, mechanics, and optics (Westfall 1980b). Einstein, in his young and miraculous year, not only laid down the principles of special relativity, but also wrote four other fundamental papers, including one on Brownian movement—again a sweep from the very great to the very small (Miller 1981).

Darwin had early aspirations, which he soon abandoned, of including the origin of life in his theory of evolution. Later in life, he made a serious effort to develop a genetic theory for the transmission of organic forms from one generation to the next. He failed in this. Nevertheless, his theory of evolution took in all of life, not only from simple organisms to higher mammals, but from apes to man—"going the whole ourang" (Gruber 1981e, 1985e). In one of his early notebooks he wrote, characteristically, "Mine is a bold theory, which attempts to explain, or asserts to be explicable every instinct in animals" (D Notebook, p. 26, written in 1838; see Gruber, 1981e).

Piaget set himself the task of explaining all intelligence as forms of adaptation. Most prominent in his thinking is the constant movement between the child and the scientist: from the beginnings of human intelligence to its most advanced forms, as he believed. But his aspirations were even wider, hence his persistent efforts in biology.

The breadth of each of these life programs imposes its mark on each network of enterprise in a number of ways. First, even though ultimate unity may be the goal, the widely different tasks embraced within each such network require different techniques, different conceptions, and different collaborators. This stimulates the further differentiation of the network. Second, both the width and complexity of the network, together with the difficulty of the chosen tasks, guarantee that the effective realization of the program as a whole will take a long time. Holmes (1985) has effectively drawn attention to the creative aspects of the final stages of scientific writing. True, Newton had his miraculous year—but he required the next twenty to complete the sketches so wonderfully begun. He was not alone in the world: Others made intuitive sketches, too, perhaps not as wonderfully, but close enough. What makes Newton Newton is not the early sketch but the movement from it to the *Principia*.

Third, the periods of dormancy which each enterprise in such a network must necessarily undergo allows psychological space for the person to distance himself from the particular task. This allows room and time for creative forgetting, mutual assimilation of distinct schemata, and serendipitous encounters with the real world. Precisely because the net is wide, the creative person's organization of purpose makes room for the operation and exploitation of chance and intuition. Darwin commented on how going the limit opens the way for thinking on more than one level of reality.

In a geological passage on the origins of granite he wrote: "However formed, we know it to be the deepest layer in the crust of this globe, to which man is able to penetrate. The limit of man's knowledge in every subject possesses a high interest, which is perhaps increased by its close neighborhood to the realms of imagination" (Darwin 1934, 261, written December 29, 1834).

Fourth, the duration, difficulty, and complexity of the work combine to promote development of all sorts of relationships of collaboration and communication among workers in the same vineyards. The differentiation of each network means that the creative person does not have to find a perfect "soulmate." He or she can talk, correspond and collaborate with, and learn from, different people appropriate for different enterprises. In my relationship with Piaget, he was able to exploit my research ranging from object permanence in kittens to the reconstruction of Darwin's theoretical work. Meanwhile, Piaget had very many other intellectual relationships of varying durations and depths, and about different topics. Foremost among these of course, the longest, most varied, and most important, was his half-century of collaboration with Bärbel Inhelder.

I have argued that we should pay close attention to the *uniqueness* of each creative person. Even if it should happen that each of his or her several enterprises was quite "paradigmatic," the configuration as a whole would be unique. To understand scientific creativity is a many-sided task, requiring the synthesis of knowledge drawn from the history and philosophy of science, from experimental and developmental approaches to cognitive psychology and social psychology. One indispensable component of this synthesis is the close study of the individual case as an evolving system, a purposeful person at work. We need not fear that this approach will lead us to an unduly individualistic picture of the creative process. As I have tried to illustrate in this chapter, when we look closely enough at the unique individual at work, we discover him or her richly embedded in a social matrix. But the case is more than a source of information, it is a test. Our ability to construct a rich and plausible account of the way a particular scientist works and thinks should be the ultimate criterion for estimating our progress toward a psychology of science.

# Chapter 2

# The Case Study That Started It All: Charles Darwin

Darwin's story has been told often and well, especially since scholars began to study the extremely rich legacy of manuscripts as they became available in the 1950s and later. I had the good fortune to be one of the first. It was not my intention to bring historical expertise to the task, rather to explore Darwin's development through the lens of cognitive psychology, particularly as informed by Köhler and Wertheimer (Gestalt psychology) and by Jean Piaget (Genetic epistemology).

We have always thought of our work as a cognitive case study of one person thinking. Nevertheless, questions arise about Darwin's personality and about the role of social-historical forces in shaping his work. Here, I deal with some points about his "cognitive personality": his persistence, the breadth and diversity of his interests, his daring, his willingness to "go the limit"—to ask ultimate questions and search for their answers.

My study of Darwin's notebooks was almost entirely cognitive—a reconstruction and integration of several of his prolonged problem-solving efforts. But we may ask, what psychological characteristics and what circumstances enabled him to carry on so long? One of Darwin's most consistent traits was the gusto with which he undertook diverse tasks that he could see would take years to complete. For it was not only the *Origin of Species* that took decades to compose. Similar time spans are exhibited in *The Descent of Man* and in other less widely celebrated projects, such as his studies of plant physiology and plant behavior.

## Divergent Thinking or Alertness to Objective Diversity?

Beginning in 1950 with Guilford's celebrated speech to the American Psychological Association, the single most popular idea about creativity has been that it entails a great deal of divergent thinking and that, consequently, tests of divergent thinking provide valid measures of creative ability. Putting aside the issue of divergent thinking in ordinary mortals we can still ask what role it plays in creative work. It might be important, even indispensable in certain peak moments, yet absent or invisible most of the time or in most people. By now the unfortunate ambition to discover the one key variable that accounts for creative achievement has faded (although not to the vanishing point). But we still have little evidence regarding divergent thinking among the Greats.

From my reading of Darwin's writings there is little or no divergent thinking in his notebooks and correspondence and less in his published works. There is, however, another sort of variability, whose source is alertness and exposure to novel materials. During the five-year Beagle voyage, of course, Darwin exposed himself as much as possible to new experiences, new geological formations, and new species. This *diversification of experience* was not accidental: Darwin selected and sought out the situations that, taken together, would make one of the great voyages of discovery. And the alternation between time spent on board the Beagle and time ashore permitted both the study of his findings and his reflections upon their meaning. In his quiet, steadfast way Darwin continued this pattern throughout his life, with thousands of letters in an international correspondence taking the place of his youthful sea voyage.

Thus, whether or not such a pattern of intentionally widening diversification is measurable by any psychometric instruments, it is clearly part of Darwin's character to seek it out.

In Darwin's case, rather than straining to find a soupçon of divergent thinking here and there, we might do better to dwell on a characteristic that is almost the direct opposite, and present in abundance—his steadfast and industrious purposefulness. He wrote about twenty books (there are some differences of opinion as to what constitutes a book), and about 150 scientific papers, many of them very substantial contributions to science. As noted, he wrote thousands of letters, maintaining an international network of scientific correspondents.

## PROFOUNDLY REFLECTIVE OR WIDELY CURIOUS?

There is little or no evidence that Darwin was deeply interested in profound philosophical questions or questions of scientific method. He wanted to further certain ideas, and he kept his eye peeled for a few main chances. When the opportunity arose to further his causes, he took it. But he did not, as far as we can tell, have a systematic philosophical program that might have forced his hand on matters that he preferred to deal with empirically, in what Friedrich Engels referred to as the "crude English style"—i.e. mountains of fact rather than eons of reflection.

Perhaps most clearly revealing of this diagnosis was his attitude toward the evolution of Homo sapiens. For years, Darwin had been collecting information bearing on human evolution but he was not eager to expose himself to the savage criticism that he could be sure would result from publishing his views on the subject. In 1859, in the *Origin of Species* (1859), Darwin had been quite circumspect about human evolution; ten years later, it was time to take up the cudgels. After *On the Origin of Species*, Darwin would have been quite happy had A. R. Wallace accepted his offer of all his notes if Wallace were to write the definitive work on the subject of mankind evolving. But Wallace declined the offer, leaving the task up to Darwin who turned to it and produced a second classic, *The Descent of Man* to stand beside the *On the Origin of Species*. It might be argued that even there Darwin evaded the sharpest critical response by titling the two-volume work *The Descent of Man and Selection in Relation to Sex*, thus giving the book a more biological and less psychological cast (Darwin 1871). In any event, most of Darwin's written reflections on philosophical questions remained in his unpublished notebooks, some of which were labeled "Old and Useless Notes."

Several hypotheses have been advanced to explain Darwin's greatness. Alas for such hypotheses, Darwin was not the first-born son; he had an older brother, Erasmus. Furthermore, far from being his rival, Erasmus was his mentor and collaborator. Not to mention his sisters, three older and one younger, who were his first teachers (his mother died when he was eight). Did his imposing father present a target for rebellion? Here again we find reason to doubt any pat answer. Of course, the whole brood of four sisters and two brothers paid the usual Victorian emotional tribute to their elders. The boy Charles got his fair share of mothering.

And as for fathering, Charles and Erasmus had no great difficulty in quitting their medical studies in Edinburgh despite their father's ambition that they follow in his medical footsteps. Much has been made of the father's initial refusal to give Charles, then twenty-one years old, permission to join the *Beagle* voyage. But considering his age, the expected duration of the voyage (two years, though it actually took five), and the very real danger of travel in those days, some judicious fatherly hesitation seems very much in order.

Perhaps most important, Darwin was not a rebellious person, nor was he contentious. He was mild-mannered, neither aggressive nor argumentative except, of course, for *On the Origin of Species* which, in his phrase, was "one long argument."

In Darwin's life as a whole, he displayed a combination of humility (symbolized and expressed by his study of the lowly earthworm) and panache (inspired by the magnificence of coral reefs). His study of earthworms (1881), which stretched out over fifty years, was begun as a study of how they form topsoil. But it eventually bifurcated into two studies, the second being about the behavior of worms and thus a pioneering study of invertebrate behavior. This work led him to conclude that "worms, although standing low in the scale of organization, possess some degree of intelligence" (p. 61).

In an oft-quoted remark Darwin wrote, "My mind seems to have become a kind of machine for grinding general laws out of large collections of facts" (Darwin 1958, 139). Reading only that much of the paragraph in which it occurs, this quotation can be and has been used to document the anti-humane character of science. But read a few lines further on and we come to "… if I had to lead my life again I would have made a rule to read some poetry and listen to some music at least once every week … The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature" (p. 139). Darwin wrote this between the age of sixty-seven and seventy-three.

# The Eye of Reason: Darwin's Development during the Beagle Voyage[1]

*together with Valmai Gruber*

Late in the voyage of the Beagle, in April 1836, Darwin visited the Keeling Islands in the Pacific. There he had his first opportunity to examine coral reefs and to test his theory of their formation, a theory he had arrived at quite deductively while still on the west coast of South America. On leaving the islands he wrote: "I am glad we have visited these Islands; such formations surely rank high amongst the wonderful objects of this world. It is not a wonder which at first strikes the eye of the body, but rather after reflection, the eye of reason" (Darwin 1934, 399-400).

In examining the voyage of the Beagle as a phase in the development of Darwin's scientific ideas, much of our effort will be devoted to a discussion of over two thousand manuscript pages of scientific notebooks which Darwin kept during the voyage but which have been neglected ever since.

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Ex conchia omnia—all things from the shell—Erasmus Darwin's family motto poses a question, not an answer. In Charles Darwin's case, broadly speaking, we need to discover the way from his grandfather's vague poetic conception of a world taking shape through struggle to Charles' realization of this conception in a trenchant scientific argument.

In his poem, *The Origin of Society*, Erasmus Darwin wrote:

> From Hunger's arm the shafts of Death are hurl'd,
> And one great Slaughter-house the warring world! (Darwin 1803, Canto IV, lines 65-66)

1. The substance of this paper was read at the 1958 annual meeting of the History of Science Society, Washington, D. C. We wish to thank Mr. Robinson, Down House, Mr. H. R. Creswick, Cambridge University Librarian, and Mr. P. J. Gautrey of the Anderson Room, for their cooperation in making manuscripts available to us. We also gratefully acknowledge financial assistance received from the American Philosophical Society and from the Council on Research and Creative Work of the University of Colorado.

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Describing the Pampas in his *Journal*, Charles wrote of "one wide sepulchre" of fossil bones. And sixty years after Erasmus, he wrote, in the final passage of the *Origin of Species*: "Thus from the war of nature, from famine and death, the mostexalted object which we are capable of conceiving, namely the production of the higher animals, directly follows" (Darwin 1859).

Not only the phrasing is similar, but Erasmus too passed from the note of struggle sounded in the couplet quoted to the same quest for solace in some more hopeful outcome of struggle, and he found it in a similar place. After pages of panegyric couplets on the fecundity of organic nature, he wrote:

> "The births and deaths contend with equal strife,
> And every pore of Nature teems with life." (Darwin 1803, Canto IV, Lines 379-380)

It is no wonder that Charles Darwin in 1838, in one of his first notebooks on evolution, scribbled: "My handwriting same as Grandfather." (Darwin, vol. 125, "M notebook," 83, written August 16, 1838).

We would not dwell so much on the relation between Charles and Erasmus were we not convinced that the poetic mood is a scientifically fertile approach to nature. There is, moreover, a special need to invoke the ghost of Erasmus Darwin in order to explain Charles Darwin's early gravitation toward natural history. As an explanation, this personal ghost is a useful companion to the *Zeitgeist*, which, while it explains everyone, explains no one in particular.

In passing from Erasmus' *Origin of Society* to Charles' *Origin of Species*, we should trace with care the voyage of the Beagle, for it was on that circuitous journey that Charles Darwin's conception of himself as a man of science finally took shape.

At Cambridge Charles was known as "the man who walks with Henslow." His teacher, Henslow, was a botanist, but what Darwin gained from him was less botany than entrée into a distinguished company of professors. Ostensibly, he was at Cambridge to prepare himself for a life as a minister in a "very quiet parsonage," as he later wrote one of his sisters (Darwin 1945). And when the opportunity to join the company of the Beagle presented itself, he persuaded his father to let him go with the argument that it really would not unfit him for his clerical career. Secretly, his sceptical, tyrannical father, freethinker Dr. Robert Darwin, may have been relieved to see his unfavored son at one stroke escape the clutches of the clergy and remove himself from the family scene for a long voyage.

Although it is true, as Darwin's biographers have emphasized, that three other nominees for the post of naturalist to the Beagle had refused the offer, and that Darwin got the position by default, Henslow's nomination was no mere whim. Under the spell of Humboldt's *Personal Narrative*, Darwin had been looking for a ship to take him to Teneriffe. Likewise, his sudden spurt of interest in geology, just after taking his final examinations at Cambridge, leading to his geological tour of North Wales with Adam Sedgwick, was clearly part of a growing purpose to become some sort of man of science, on the model of the peripatetic scientific litterateur Alexander von

Humboldt. And yet, true to his emerging style of life, a style of small self-deceptions and large truths, he embarked on the voyage persuaded that he would return to the "quiet country parsonage."

When we look at the microstructure of human thought, it appears blindingly swift. So much happens in a few minutes that it is impossible to record it all, and most of it is forgotten an hour or two later. But when we hook at the broader currents and changes of direction in thinking, it seems to move much more slowly.

Darwin had to go through several fairly distinct phases of thought before beginning to think in a disciplined way about organic evolution. When he embarked on the voyage of the *Beagle*, his conception of the universe was one he took from Gilbert White, Humboldt, Paley and the Reverend Professors of Cambridge. In this universe a hazy kind of harmony and order prevailed, occasionally interrupted by some great debacle, such as the Flood. An essential feature of this order was the interrelatedness of living things. Under Lyell's influence, Darwin moved into the second phase: order prevails continuously, in the sense that the same natural laws apply eternally; harmony is not so much an issue, for the focus of attention is primarily on the inorganic world—but in so far as organic nature is treated, there is a note of struggle. Change occurs constantly, not in the form of great cataclysms, but as a series of small changes which express the natural order rather than violate it. For Darwin, his work on the formation of coral reefs is the culmination of this phase: a biological phenomenon (the way in which the coral organism grows) is the means used to clarify a geological one (the various forms of coral reefs). In the third phase biology becomes the central issue, and geological phenomena are used to clarify biological ones; from the history of the earth's crust Darwin begins to discern the history of its inhabitants.

Each phase defines a domain of problems and leaves a complementary domain untouched. In the first phase, the problem domain is classifying the objects of nature, be they birds, rocks or plants. The system of classification and the items entered in it comprise the natural order, and the general task is to discover this system. Changes of state from one order to the next are considered to be an extrascientific problem, the work of Creation.

In the second phase, it is these very changes of state which become the problem domain, the general task being to show that one homogeneous set of scientific laws can explain all such changes. But with regard to Darwin's thought in this phase, the problem domain is restricted to changes in the earth's crust—physical geology. The unexamined complementary domain is the series of changes in the earth's inhabitants. In phase three, the problem domain is the series of changes in organic forms—vertically in geological space and horizontally in geographical space. The task Darwin assumed was to erect a single rational structure that would account for the facts of geographical distribution and the differences between extinct and living species. The unexamined complementary domain (of which Darwin was fully aware) was the biological locus of heritable variations, what we now call the gene. Darwin used the existence of such variations as a cornerstone of his theory; but he never succeeded in explaining them, and he had the discipline to leave this great and attractive problem domain alone for nearly thirty years.

It probably took Darwin the full five years of the *Beagle* voyage, 1831-1886, to work through from phase one to phase two. It took him perhaps the next five or seven years to make the full transition from phase two to three, culminating in the essays of 1842 and 1844. The tortuous history of phase three itself, to which Robert Stauffer has recently contributed his transcription and analysis of the "big book"—the long manuscript preceding the *Origin of Species*—occupied the years from 1845-1859, culminating, of course, in the publication of the *Origin* (Darwin 1909; Stauffer 1959).

What follows deals with the transition from phase one to phase two, the change from thinking about natural history as a science of classification to thinking about it as a science of process. As we see it, this change is the main substance of Darwin's intellectual development during the voyage of the *Beagle*.

During the voyage, Darwin wrote copiously. Written on large sheets, most of them about 9 x 11 inches, his notes include the following:

*Table 1.*

| | |
|---|---|
| Geological notes | 1383 pp. |
| Zoological notes | 368 pp. |
| "Personal" journal | 779 pp. |
| Total | 2530 pp. |

In the fifty-five months of the voyage, these alone amount to a production of over a page and a half per day, including the days spent in the saddle or afoot in his numerous expeditions ashore.

In these large notebooks, specimens are described, observations recorded, incidents narrated, and most important of all for our purposes, ideas are unfolded, puzzled over, rejected and improved.

The notebooks were generally written shortly after the event, whenever Darwin had time to sit down and organize his material. But some of the notes, especially in the geological section, are longish essays, drawing together and reflecting upon the materials and ideas developed in several expeditions, such as an essay on the geology of Patagonia and another on the formation of coral reefs.

In addition, Darwin kept at least twenty-four small notebooks in which he jotted down on-the-spot notes to be transcribed and enlarged upon later. These notebooks, which have been interestingly described by his granddaughter, Nora Barlow, include several catalogues listing specimens by number and giving brief descriptions. Finally, there were the letters. In addition to all the family letters and other letters, to friends, there were forty to his teacher Henslow containing enough material of scientific interest for Adam Sedgwick to read excerpts from them to the London Geological Society and Henslow to the Cambridge Philosophical Society (Darwin 1835). These excerpts were also privately printed for the members of the Cambridge Philosophical Society while Darwin was still away and without consulting him—a point which he protested weakly and with perhaps some pride.

The scientific notebooks mentioned above deal almost entirely with geology and zoology. There must have existed more notes on botany than we have seen—at least a catalogue of the specimens sent home. Although we have not yet come across such botanical notes, we do not think the substance of the following remarks would be much altered by anything we would find. Of all the branches of natural history, Darwin was at the time least concerned with botany.

In his published *Journal of the Voyage* he admitted that:

> ... from my ignorance of botany, I collected more blindly in this department of natural history than in any other; so that certainly it was not intentionally that I brought the different species from different islands. If, indeed, I at all noticed their resemblance, I probably collected second and third species as duplicate specimens of the first. (Darwin 1839, 629)

This passage, of course, refers to his work in the Galapagos Archipelago. None of the books or monographs resulting from the Beagle voyage deals with botany, and in Darwin's published account of the voyage, botany always gets the shortest shrift. It was not until after the appearance of the *Origin of Species* that he began to publish much in the field of botany—and then, of course, in earnest.

A study of the larger scientific notebooks helps to give a picture of the ebb and flow of Darwin's preoccupations and of the slow, vacillating growth of his allegiance to Lyellian geological theory. This information, in turn, may help to clarify our conception of the rate and character of the development of his evolutionary ideas during these early years.

First let us compare the actual amount of work he did in geology and zoology during the four and three-quarter years of the voyage, using as a rough index the number of pages devoted to each subject.

With the exception of the last year, 1836, the amount of geological work increases steadily throughout the voyage, whereas, with the exception of the third year, 1834, the zoological work decreases steadily. Except in the first year (1832) the geological work always far exceeds the zoological.

In both fields there was a notable spurt of activity stimulated by the month-long visit to the Galapagos in September-October of 1835. Both his geological and his zoological notes for this period are more than three times more copious than his average rate of productivity.

*Table 2.* Number of pages

| *Year* | *Geological* | *Zoological* | *Geological / Zoological* |
|---|---|---|---|
| 1832 | 85 | 145 | 0.59 |
| 1833 | 119 | 62 | 1.92 |
| 1834 | 303 | 91 | 3.33 |
| 1835 | 531 | 46 | 11.54 |
| 1836 | 200* | 22* | 9.09 |
| Galapagos (1 mo. 1835) | 80 | 25 | 3.20 |

*corrected for number of month

But even so, the geological notes on the Galapagos are more than three times as long as those on zoology. Darwin, on first viewing the Galapagos, was far more interested in the peculiar volcanic formations of this archipelago that he was in the peculiarities of its organic forms which he later made famous.

This point is corroborated in his catalogue of zoological specimens of the *Beagle* voyage, now kept at Down House. There is nothing in these notes to show that while he was on the spot he abandoned his geological preoccupations to any great extent in order to study the fauna of the Galapagos with unusual thoroughness, nor are there any remarks pregnant with evolutionary thought. None of his notes for the remainder of the voyage, now in its last year, shows any remarkable increase in zoological interest. On the contrary, the decline mentioned above continues, and while the geological notes also decrease somewhat, they maintain something like a nine to one superiority over the zoological notes.

It is not until three months later in a diary entry written in Australia (January 18, 1836) that we find a clear cut passage suggesting any evolutionary stirrings. This is a passage in which he muses on the peculiarities of geographical distribution, entertaining and then rejecting the hypothetical thoughts of an Unbeliever. He concludes with the idea of multiple creations: "... one hand has surely worked throughout the universe. A Geologist perhaps would suggest that the periods of Creation have been distinct & remote the one from the other; that the Creator rested in His labor." (Darwin 1934, 383).

This passage was written in Australia, two and a half months before he got to the Keeling Islands where he finally had the opportunity of testing the theory he had developed on the formation of coral reefs. His success there, we believe, finally convinced him of the penetrating power of the "eye of reason," and by the same token confirmed him in his uniformitarian geological views. He did not write such a creationist passage again. But if uniformitarianism is a long way from Creation, it is also a long way to the *Origin of Species*.

Now Nora Barlow has called attention to a passage from an ornithological notebook in which Darwin concludes a description of the varieties found on different islands in the Galapagos as follows: "... the Zoology of Archipelagoes will be well worth examining; for such facts would undermine the stability of species" (Barlow 1935).

Lady Barlow has suggested that this passage establishes "beyond doubt" the date when Darwin's ideas on the mutability of species crystallized. She has not, however, specified that date, nor have we been able to date this passage. The notebook in which it occurs appears to be a collation of ornithological materials collected during the entire voyage. Our guess, based on the format of the notes and the watermark of the paper, is that the whole notebook was written on the way home, in the last few months of the voyage, or nearly a year after his encounter with the Galapagos.

The date of this ornithological notebook is important enough to be considered in some detail. The notebook, now kept at Down House, is of a paper watermarked 1834, yet the first entry is dated 1832. This fact and the uniform appearance of the notes strongly suggest that they were all written in one brief period, rather than scattered over the whole voyage. The reason for suspecting that the notebook was written on the way home is the existence of a similar notebook (same 1834 watermark, same 1832 starting date, same uniform appearance) in which the final entry is Ascencion, July 1836. Moreover, we are fairly certain that Darwin did use the return voyage for writing up his notes (Darwin 1945, 252).

It would indeed be valuable to know just when Darwin first permitted himself to write that certain facts "would undermine the stability of species": was it a quick flash of insight just after leaving the Galapagos or a reflection upon the whole voyage as he drew his ideas together, nearing home?

In the zoological notes of the large notebooks—which can be dated as September 1835 (during the Galapagos visit)—his undoubted interest in the unusual creatures of the Galapagos does not seem to have produced any evolutionary stirrings. The peculiar "variations" from island to island are mentioned twice, rather matter-of-factly. About the best we can do is the following passage:

> With respect to the Land Birds their extreme tameness has been described in my private Journal. Little birds can be almost caught by the hand. They will alight on your person and drink water out of a basin held in your hand—Must not this arise from the entire absence of all Cats and Mice and other similar animals and those Hawks which pursue small birds? (Darwin, ULC, vol. 31, 343-344).

In short, although Darwin's ideas about species may have been stirred by his Galapagos impressions, at first they stirred only slowly and faintly.

We have dwelt at length on this point because it bears on the character of scientific insight. It is a commonplace that great insights occur only to the prepared mind, or as Darwin himself might have put it, great observations only to "the eye of reason." But the time it takes to prepare a mind has not been well examined. In stressing the youthfulness of many creative scientists at the time of their greatest attainments, one may overlook the long and tortuous period of preparation. Indeed, Darwin was only twenty-eight when, very deliberately, he "opened his first notebooks on the transmutation of species." But by that time lie had filled up many a notebook in other domains.

We have looked carefully through Darwin's zoological notes, and while they contain few suggestions of evolutionary thought, three significant themes occur repeatedly. The first is Darwin's difficulty in classifying new species within the existing systems of classification—but with no particular criticism of the systems. The second is the interrelatedness of living organisms. Here are two examples which we have chosen because they also suggest a certain progression in Darwin's thinking. In June 1833, he wrote on the peculiar absence of dung-feeding insects in South America:

> After being accustomed to the great numbers of coprophagous insects in England,—It was at first with surprise that I here found the ample repast afforded by the immense herds of horses and cattle almost untouched ... M. Video was founded 1725 ... Cattle and horses here perhaps only for about 80 years. This absence of coprophagous beetles appears to me to be a very beautiful fact; as showing a connection in the creation between animals so widely separate as mammalia and Insecti Coleoptera, which when one of them is removed out of its original zone can scarcely be produced by a length of time and the most favorable circumstances ... (Darwin, ULC, vol. 30, p. 200).

A similar theme occurs a year later. In July 1834, on Chiloe, he commented on a report that the indigenous lice live well on the Indians but die in three or four days on European sailors: "If these facts were verified their interest would be great—Man springing from one stock according to his varieties having different species of parasites.—It leads me into many reflections." (Darwin, ULC, vol. 31, 315).

The last sentence is crossed out, perhaps because he decided to defer these reflections.

The third theme which recurs in the zoological notebooks is Darwin's constant surprise and delight at finding new species in new places, coupled from time to time with a few reflections on the general subject of geographical distribution.

When we turn from the zoological notebooks to the geological, the picture is entirely different. Almost from the very beginning definite hypotheses are formulated, tested, and reformulated. At least one important change in vocabulary becomes a matter of concern, reflecting shifting theoretical allegiances. Broader and broader integrations of ideas are attempted and pursued, eventuating in connected essays inserted in the notes and in the personal journal. During the voyage Darwin began to think of himself more and more as a geologist, and toward the end of it he wrote to Henslow asking to be proposed as a member of the Geological Society of London. He should not have anticipated any hesitation, as some of his work had already been heard with approval there.

Darwin's intense interest in geological work leads to one difficulty in re-tracing his ideas. Far more than in the zoological notes, he has shuffled and re-shuffled his papers, assembled and reassembled his thoughts. Some entries cannot really be dated within a year. But most entries are dated, and some doubtful ones can be cleared up by considering the year the paper was manufactured, particulars of format, and internal evidence in the written matter itself. All in all, one can reconstruct a satisfactory chronological account of the development of his ideas.

From the very first page of these notes, mingled with the descriptive material, there is an obvious pleasure in making hypotheses, and this within the framework of a peculiar blend of uniformitarian and creationist ideas.

In his entries for January 17-18, 1832, describing Quail Island, Cape Verde, it is quite clear that he believes in something like the Flood, but he also describes continuous, on-going and gradual geological processes: "There is now going on a very remarkable process on the coast of this island: viz: the formation of an extremely hard conglomerate ... daily ... increasing under my own eyes" (Darwin, ULC, 19). And on the next page: "I have not mentioned a small covering of diluvium on the Western side of the Island.—At first I thought it merely debris from the upper feldspathic rock.—but on examining ... It looks to me like a part of the long disputed Diluvium" (p. 20).

These lines were written in the first month of the voyage, en route to South America. Sometime later, possibly in September, 1836, on the way home, when he again stopped in the Cape Verde Islands for a few days, he added: "This account was written before I had examined any part of St. Jago ... I have drawn my pen through those parts which appear absurd" (p. 20). The parts crossed out, of course, include the sentence about "the long disputed Diluvium."

Less than a month later, in February 1832, writing about St. Jago, he re-examines the same diluvial theme, but the conclusion has a less biblical tinge: "I am decidedly of an opinion that these valleys were formed by great bodies of water and not by gradual effects ..." (p. 33).

His discussion of the action of water ends: "I thought it might have been the sea.—but the valleys terminate and divide in so usual a manner that I was obliged to give up this idea. & go back to the torrents of rain that usually are said to accompany volcanic action" (p. 35).

The long discussion of the valleys of St. Jago also contains some conflicting remarks on the age of the earth. Remarking on the age of an Adansonia tree, he suggests that 6,000 years is "a large fraction of the time that this world has existed." In the next sentence: "Of course the valley must be still older ..." After some description of the actual rock formations, he concludes with a sentence suggesting that he was then struck by the apparent immutability of species: "To what a remote age does this in all probability call us back and yet we find the shells themselves and their habits the same as exist in the present sea ..." (p. 34).

Regardless of the conclusion he happened to draw at that early stage of the voyage, it is clear that he was already beginning to focus attention on some of the crucial issues, and that at least in the field of geology he was ambitious to be far more than a thoughtless collector of specimens.

In October, 1832, he arrived in Bahia Blanca in Brazil, and made several excursions to a nearby fossil bed at Punta Alta. His description is still written in the language of catastrophe:

> This mixture of such quantities of bones of land animals with shells, must be explained by supposing a body of water sweeping over the plains and bringing with them the bones strewed on the surface and the living animals ... The upper gravel only differs from the lower in containing fewer bones (We may conjecture the first inundation swept the plains clear) and that the action of water is evident in breaks and furrows on the Tosca.—This latter I imagine to have been deposited under similar circumstances but in calmer water.—it is impossible to behold it without immediately saying it is the mass of earth which a debacle tearing across the country would deposit. (p. 65)

During the year following this first visit to Bahia Blanca, we can find passages indicating the direction of change in Darwin's ideas. For instance, from Bahia Blanca he went to Monte Video and there was beginning to be impressed by the possibility that gradual, non-violent changes might, in a long time, have large effects:

> It may be observed how strange it is that in a country which has suffered so remarkably little from the convulsions of nature that this stratification should be vertical.—How is it possible that horizontal plates, deposited beneath water should be elevated through a space of 90°—and yet the country be one of the most unbroken on the face of the globe. (Darwin, ULC, vol. 34, p. 6)

But a few months later, January 1833, Fort Desire, he is again writing about the "diluvium" and, in his own words, "a cause much more violent than now exist" (pp. 29-34). In August and September of 1833, Darwin returned to Bahia Blanca, on an overland journey in the saddle. His experience had broadened, and he was moving closer to uniformitarianism: "Having revisited P. Alta after seeing the neighboring country my opinion respecting its geology is completely altered ... Many phenomena are best explained by small modern upheaval ..." (Darwin, ULC, vol. 32, p. 74).

One of the most important kinds of evidence that convinced Darwin of the correctness of Lyell's views was the appearance of recency in fossil specimens found far from their natural habitat, suggesting that although some geological changes are remote in time, many are recent. If geological change can be recent, it can be going on today—according to a homogeneous set of laws throughout. Darwin was, therefore, on the lookout for any signs of recent geological change. A passage written in 1834—not his only use of linguistic evidence—illustrates this interest:

> 1834 Nov. Arch. of Chiloe.
> In my notes to S. Carlos I have attempted to show the land to this day is rising: a proof of it exists in the names of places—'Huapi' in the Indian Language means islands. Now many peninsulas, joined by low land have at the present day the Huapi affixed to them.—The inhabitants state they were formerly islands. (Darwin, ULC, vol. 35, p. 297)

By 1835 the change is complete. In describing the valley of Copiapó in Chile, he writes: "From the description of the valleys in this line of coast, an extent of about 400 miles, the following conclusions appear to me inevitable.—That the sea, during a long and quiet residence deposited those masses of Shingle stratified with seams of sand and Clay which in Europe would be called Diluvium." Note the specific disclaimer of the term "Diluvium." He goes on to explain how a variety of specific geological formations in the region can be explained by the "quiet residence" of the sea (Darwin, ULC, vol. 37, 675-676).

Thus it took Darwin at least two years, and possibly three, from the time he set out on the voyage and began to read Lyell to become firmly convinced that the history of the earth's crust could be explained by means of one homogeneous set of laws, that these laws were still operating, and that—viewed on a large enough scale of space and time—geological events of cataclysmic proportions from a human point of view were only small incidents in a slow process of change.

Following Lyell's prescription, he became interested in coordinating his fossil finds with other geological data; from an early date he took great pains to identify the strata in which his fossils occurred. For example, in October 1832 en route from Bahia Blanca to Monte Video, the Beagle stopped briefly at Monte Hermoso and Darwin went ashore. He made a good haul of fossils, including some bones which he thought belonged to the "antediluvial Megatherium" (Darwin 1934, 106). Most of his attention was given to the formation in which the fossils were found: "The remains of this animal have always been described as being in superficial gravels and caverns—or as it is sometimes called, diluvial formations.—Now it appears to me that the beds which I have described do not come in this class." He gives his geological reasons and then concludes: "I have been thus particular in describing those beds in which organic remains occurred—for the comparison of formations in different parts of the world which contain animals of equal grade in the chain of nature seems at present to be much wanted in Geology" (Darwin, ULC, vol. 32, 58-60).

Naturally enough, in going through these notes we were at pains to look for signs of the growth of evolutionary thought. During the first year of the voyage there are a few passages, one of which we have already cited, that suggest a belief in the immutability of species. But as to a shift toward mutability, the notes offer little. There is one suggestive passage, about Chiloe, off the coast of Chile, probably written in January 1835, rather late in the voyage: "To what an epoch does this consideration lead the mind when in the older strata, not only is the local habitation of species altered, but the species and even genera are changed" (Darwin, ULC, vol. 35, 303). But it should be remembered that this remark can be readily assimilated to the idea, expressed by Lyell in the *Principles of Geology*, of a succession of organic beings called into existence by a succession of creative acts. There is some evidence[2] that Lyell himself did not entirely believe in a series of divine creations when he wrote about it in 1830, but in 1835 Darwin probably did. Whatever the succession of species and even genera may have meant to Darwin, it certainly did not take hold of him with any force. He was preoccupied with his grand ideas on the elevation of South America. Darwin has given a good description of the kind of hypotheses that interested him during this period of the voyage, in a passage written in Chile, sometime between August and November of 1834.

> Often when sailing about the intricate bays and channels in the South I had tried to picture to myself what appearance this country when elevated would assume.—it was no ordinary satisfaction to find in Chili answers to all my conjectures. I will now give what more purely geological reason I possess in support of these views. (Darwin, ULC, vol. 35, 404)

The passage quoted is one of many exemplifying the way in which Darwin's hypotheses seem to have taken shape in the form of visual imagery—a characteristic about which he wrote explicitly later on.

In our opinion Darwin's remarks on the process of extinction, which he was led to consider by virtue of his many fossil finds of extinct species, are the most directly suggestive of organic evolution in these notebooks. There are several such remarks, but none resembles the character of his later thought in the *Origin* so much as this one, written in May, 1834. Speaking of certain beds of sea shells, he writes: "A [sudden] change in the nature of the bottom, must destroy many animals, and when of great extent if the species are not in proportion more extended, they must perish from the world" (Darwin, ULC, vol. 34, 149).

Lyell had already expressed the same idea at length, so that there is nothing very original in Darwin's making this point. Nevertheless, first hand contact with some of the major facts of geographical distribution was one of the crucial advantages Darwin gained from the voyage.

His geological notes on the Galapagos in September and October of 1835 are a lengthy attempt to work out the role of volcanic action in forming these islands. The idea that most strikes his fancy is a hypothetical "mud volcano" which he discusses at

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2. Charles Lyell, *Life, Letters and Journals* (1881). See especially Lyell's letter to Poulet Scrope, June 14, 1830. Scrope was about to review the forthcoming *Principles of Geology* in the *Quarterly Review* and Lyell undertook to supply him with guidance in writing the kind of review that would win a favorable reception for the book despite its contradiction of Genesis. Lyell freely admits that he pulled his punches: "If I have said more than some will like, yet I give you my word that full half of my history and comments was cut out, and even many facts; because either I, or Stokes, or Broderip, felt that it was anticipating twenty or thirty years of the march of honest feeling to declare it undisguisedly." It is a sad commentary that Lyell's longer estimate, thirty years, takes us almost exactly to the publication date of the *Origin of Species*.

length. He has a long section on the complete absence of coral from these islands, and in the end he accepts Captain Fitzroy's hypothesis that the cold ocean currents around the Galapagos are the cause.

All in all, then, it would be a mistake to interpret the few faint suggestions of organic evolution in these notebooks as signifying the important part of Darwin's intellectual development during the Beagle voyage. He was during this period first and foremost a geologist—as indeed he wrote repeatedly in his letters home. And at that time geology to him chiefly meant the history of the earth's surface, not of its inhabitants.

If we wish to find the beginning of Darwin's evolutionary thought in the voyage of the Beagle, there is something far more interesting than a few vague hints of organic evolution. Darwin worked out a theoretical model that bears a striking formal resemblance to his later work on organic evolution. We refer to his theory of the formation of coral reefs, worked out in 1835 when he was still on the west coast of South America. Just as he had speculated on the geology of the west coast while still on the east coast, he now continued to extrapolate westward. Concomitant with the general elevation of the level of the continental land mass, he believed that there must have been a general subsidence of the ocean floor. His theory of the formation of coral reefs by "the upward growth of the corals during the sinking of the land" (Darwin 1839, p. 475) is really an extension of this idea.

The two theories (organic evolution and coral reefs) display several basic similarities:

1. Both theories contain a principle of population growth—in the case of coral reefs, the assumption is that the coral organism does not grow beyond some limiting distance from the surface of the sea. In both cases the principle of population growth is described by Darwin as struggle—in the case of coral formations the struggle is, he said, "between the two nicely balanced powers of land and water" (Darwin 1890, 24).
2. Both theories employ a general approach to physical geology, taken together with the principle of population growth, to explain the major facts of geographical distribution. In the case of coral reefs, the hypothesis of a general subsidence of the Pacific floor determines the places in which the coral organism can grow and form reefs. Occasional elevations determine the particular form of certain reefs.
3. Finally, both theories are capable of generating a continuous series of forms where direct experience had previously revealed only a few classes. In Darwin's words, summarizing his theory: "On this view, the three classes of reefs ought to graduate into each other. Reefs having intermediate character ... do exist" (p. 78). And later, "fringing-reefs are thus converted into barrier-reefs; and barrier-reefs, when encircling islands, are thus converted into atols, the instant the last pinnacle of land sinks beneath the surface of the ocean" (p. 109).

With regard to scientific method it might be added that once possessed of an idea, Darwin worked in the same way in both cases. The general theory gave rise to a host of particular hypotheses. In so far as the hypotheses were supported, the case for the theory was strengthened.

Developing the theory of coral reefs may well have provided Darwin with a simplified model on which to frame his evolutionary ideas. By the same token, it may explain his preoccupation with a creative geological idea to such an extent that he cast a blind eye at first to the importance of the biological phenomena he observed in the Galapagos and elsewhere during the last year of the voyage.

Considered as a phase in Darwin's intellectual development, then, the five-year voyage of the *Beagle* provides us with the crucial change in his view of natural history. He began the voyage conceiving of natural history as a descriptive and classificatory science confronted with a relatively static order of nature, unchanging except for catastrophic events. He ended it conceiving of natural history rather as the analysis of ongoing processes in a continuously changing natural order. Throughout the voyage, even in the Galapagos Islands, Darwin was chiefly concerned with geological questions rather than biological ones. The scientific notebooks he kept during the voyage reveal almost nothing directly suggestive of belief in, or even thoughts about, organic evolution.

As a theoretical model, however, Darwin's theory of the formation of coral reefs displays formal characteristics strikingly similar to the theory of evolution through natural selection. Although the material content of the theory of coral reefs has little bearing on organic evolution, the formal structure of the theory may have crystallized for Darwin the general approach he later used in explaining organic evolution.

On the one hand, Darwin's development provides no support for the view that scientific theories spring Minerva-like from the head of the scientist on first sight of the evidence. On the other hand, the slow growth of his thought in a number of distinguishable phases does not imply a trial-and-error process of blind groping. In an orderly way, the completion of one phase set the stage and provided the intellectual pre-conditions for the emergence of another. There is, in fact, a certain quality of inevitability and perhaps great significance in a sequence of items in Darwin's Diary:

> 1837 May: Read papers on Coral Formation, and on the Pampas, to the Geological Society.
> July: Opened first notebook on Transmutation of Species. (Darwin 1903, vol. I. p. xviii).

# THE EMERGENCE OF A SENSE OF PURPOSE: A COGNITIVE CASE STUDY OF YOUNG DARWIN[1]

It should be said at the outset that by discussing how one may go beyond formal operations we are also striving together to go beyond Piaget. This is our tribute to a great man. We should take some cognizance of his passing. We should also take some pride in the fact that this vigorous group of writers has sprung up not only in criticism of, but also in continuation of, the work that Piaget began.

This chapter will be somewhat different from most of the others in that it will center around a case study of a single person, Charles Darwin. That focus may require some justification. The authors of this volume are embarking in a new adventure in understanding the growth of mind. Some view of the thinking person as a system, as a whole, is needed. Another way of putting the matter is to say that the more advanced and precise the stage of scientific work, the more a grounding in the natural history of the subject of inquiry is required.

A detailed case study provides one of the best ways of obtaining such a view. For some years I have devoted much of my efforts to developing an approach to cognitive case studies of creative work. The purpose of this book provides an opportunity to link those efforts with more general studies of cognitive development and to clarify, maybe even to answer, some questions about adolescence and early adulthood. But first a few caveats.

## FIRST CAVEAT: ON THE NECESSITY AND SUFFICIENCY OF FORMAL OPERATIONS

It is not at all clear that everyone attains the stage of formal operations (Gruber and Vonèche 1976). Even among those who do complete this magnificent human accomplishment, it is certainly clear that not everyone goes on to harness these skills (as I prefer to think of them) to a point of view and a set of tasks that will permit the conduct of creative work and the organization of a creative life.

If it is supposed that somewhere between 25% and 100% of adolescents do attain formal operations, it is immediately clear that this attainment is not *sufficient* to guarantee the emergence of a creative life. On the other hand, there is not enough known as to whether formal operations are *necessary* for creative work. At a different operational level, there is at least some evidence to suggest that progress toward concrete operational thought is associated with a reduction in artistic, creative expression (Gardner 1980a).

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## SECOND CAVEAT: ON THE RELATION BETWEEN NOVELTY AND NEW OPERATIONS

It may very well be the case, one as yet largely unexamined, that not everything valuable in the human intellectual economy is an operation. And, certainly, not everything new that happens need result from the emergence of a new operation. Clarifying the concept of intellectual operation is a task that confronts everyone in this volume. An operation must be something like a tool that can be applied to many things. In addition to this breadth of application, a tool remains distinct from the matter to which it is applied and which it transforms. This opens up the possibility that the iteration of this process of application of tools to contents or domains may be what produces novelty. So in studying creative work, one need not assume that if something dramatically new appears, it must mean that a new operation has emerged.

## THIRD CAVEAT: ON COGNITIVE UNIVERSALS AND UNIQUE ACHIEVEMENTS

Most work on intellectual development has focused exclusively on cognitive universals, that is, species-wide cognitive characteristics. Piaget set the tone by reinventing Baldwin's term *genetic epistemology* and making it his emblem. This was probably a good strategy for making a first sketch of important features of development in infancy and childhood. But we have as yet no strong reason to believe either that development stops in adulthood or that it continues to follow even an approximate standard course. And, certainly, when turning to the study of creative work, the domain of cognitive universals that Piaget and others have centered upon has been left. In a creative person like Darwin certain potentialities are maximized. It may well be that the most interesting properties of the system under study are not merely not universal, but unique. The important book by David Feldman (1980), *Beyond Universals*, discusses this issue in extenso.

Since science aspires to generality and universality, any proposal for a scientific study of unique configurations or systems seems to be almost a contradiction in terms. But not necessarily. In some branches of science, the study of unique configurations is recognized as a central task. A biologist describing a new species is not only interested in showing how it is just like some other species, but also in precisely how its morphology, physiology, and functioning distinguish it from others. These give it its special character. Organic chemists devote much of their energy to deciphering the *unique* character of various complex molecules. What is *general* is the style of analysis. What is *universal* is the conformity to a small number of laws forming a coherent group. Without lively movement between interest in the unique and in the universal, these fields would be much the poorer. The same applies to our work in intellectual development. Those accustomed to measuring, manipulating, and correlating variables across a number of subjects are usually quite happy to agree that the case-study approach provides a sort of natural history setting and prologue for more rigorous research. This makes sense, and it is further argued, with Kurt Lewin (1935) and others, that the demands of the individual case study also provide the acid testing ground for rigorous theory.

This point may become particularly important in connection with the topic of this book. As the developmental tasks of childhood are completed, especially in modern society, the person must search for and construct his or her special place in the scheme of things. If there is no way of dealing with this maturing and heightening of individuality, researchers may be incapable of understanding fundamental development phenomena.

All such issues connected with individuality arise with redoubled force when one considers the life and thought of a person who, often quite unknowingly, organizes his or her energies around the complex ensemble of tasks entailed in creating something new.

## THE EVOLVING SYSTEMS APPROACH

I turn now to a sketch of the work my students and I have come to call the *evolving systems approach* to cognitive case studies of creative work. Each general idea presented will be illustrated with material from the life of young Charles Darwin, mainly between the ages of twenty and thirty. Since case studies do not fit nicely into thirty-page chapters, the material will have to be compressed severely in order to cover the ground.

It is useful to conceive of the person as being comprised of three organizational subsystems: (1) an organization of knowledge; (2) an organization of purpose; and (3) an organization of affect. All of these interact with and overlap each other. Nonetheless, they each maintain a certain degree of independence, including their partially independent evolution within the thinking person.

### *Organization of Knowledge*

The more it is studied, the more it is realized how complex and densely packed is this first subsystem. It is quite helpful to consider creative scientists as maintaining belief systems that orient them in their work and into which they assimilate new experiences. The belief system is not constructed *de novo* by each creative person, but he or she must reconstruct it in order to assimilate it. In so doing, changes are introduced into the cultural heritage thus being transmitted, and these changes constitute openings for further change. At the same time, experiences arise from the person's intercourse with the world. But this world is not an environment standing outside the person, static and alien, waiting only to impose itself. It is a world chosen by the purposeful play of attention. It is also a world constructed in a personal way by the interpretations the individual incessantly makes of it.

Viewed in this way, it almost seems a wonder that, once it gets started, cognitive change does not become a runaway process. There must be robust control mechanisms that keep it within limits, making it possible for the person to remain in contact with contemporaries, and to develop effective innovations that can be successfully communicated to others. Such controls may in fact be quite similar to those exercised by individuals with no desire to innovate, those who devote their efforts to keeping things as they are. A small difference in organization and emphasis can accumulate to large consequences.

As discussed elsewhere (Gruber 1981e), the creative person must develop and bring to bear on his or her emerging subject a novel point of view. There is no need to think of the individual as solving problems in a mysterious way called "genius." Given a novel point of view, and operating within it, the consequences seem natural. Indeed, they might be the same for a number of other thinkers if only they could share that perspective. But the development of a new point of view takes place in a series of phases. It may be quite a protracted process, involving problem solving (among other activities) as one of the tools used to help develop the point of view. So, it may be said that, rather than thinking in order to solve problems, the person striving to develop a new point of view solves problems in order to explore different aspects of it and of those problems and of the domain to which those problems apply.

Darwin constructed such a new point of view. Soon after he set out on the voyage, he found himself confronted with the contradiction between the Catastrophist and biblically oriented geology he had studied at Cambridge University on the one hand, and the Uniformitarian geology of Charles Lyell, whose new *Principles of Geology* (1830-1833) he received as a gift upon embarkation on the other. His thinking through this contradiction took place in an unprecedented and everchanging setting, the circumnavigation of the globe in a five-year voyage by a trained field naturalist.

There was another contradiction to be confronted, one that concerned organic evolution itself. None of Darwin's teachers at Cambridge were evolutionists, and insofar as they discussed the question, they opposed it. Lyell, who, through his *Principles* became Darwin's mentor, wrote a vitriolic and scornful critique of evolutionary theory as exemplified by Lamarck. In contrast, Darwin's grandfather, Dr. Erasmus Darwin, had been a famous eighteenth-century evolutionist. In his adolescence, Charles had read *Zoonomia*, the evolutionary essay, and was apparently quite favorably impressed by it. This is reflected in his account of his later disappointment on rereading it. Moreover, one of Darwin's teachers at Edinburgh University, which Darwin attended before Cambridge, was an enthusiastic Lamarckian. This was Professor Robert Grant who was very important to Darwin. They took walks together and young Darwin's field research provided the material for a paper that Grant published (Barrett 1977).

But evolution was distinctly not the order of the day for Darwin during the five-year *Beagle* voyage around the world. His empirical work included field work in geology and much collecting, describing, and preliminary classification in botany and especially in zoology. His theoretical work, following increasingly Lyellian lines, was restricted to geology. In the thousands of pages of scientific notebooks that he kept during the voyage, there are few if any hints of evolutionary thought (Gruber and Gruber 1962). In the Galapagos archipelago and elsewhere, he failed to exploit certain biogeographical opportunities that would have excited his attention had he been concerned with evolutionary questions. Thus, as late as October 1835, when he visited those islands, the collections he made were woefully incomplete. These had to be supplemented years later when their significance was understood (Sulloway 1982).

Nevertheless, Darwin's knowledge of his grandfather's work, of Grant's, and even of Lamarck's, as presented and trampled on by Lyell, may have left him with an *arrière pensée* or a directive tendency. This tendency may have helped him to move as rapidly as he did toward evolutionary thinking. This took place on the last leg of the voyage and soon after his return to England.

At every point in the story, then, Darwin is seen constructing and reconstructing his belief system and controlling the play of attention in ways determined by it. The growth and changes in his belief system during this period can be presented in a series of diagrams.[2] Figure 1. shows six phases. The first three represent the development of Darwin's point of view up to the point where he began to think seriously about the possibility of a scientifically defensible theory of evolution. In these diagrams, an arrow represents a "causal" relationship such as the Creator making organisms. A line represents a noncausal relationship, such as adaptation. One might complicate the diagram with causal arrows emanating from the Creator, showing Him or Her as providing such noncausal relationships (for example, from C to the line OP in Figure 1. A), to show that the belief system includes the idea that the Creator designed such adaptations.

At some point early in the voyage, Darwin believed that the Creator had created the organisms of the earth and their physical environment, the earth itself. Following this, he converted himself, over a period of some two or three years, to Lyell's Uniformitarian geology. He came to believe that the physical universe evolves according to natural laws, operating uniformly throughout time, today exactly as they had done untold millions of years before. These first two phases are shown in Figure 1. A and Figure 1. B.

But Figure 1. B contains an obvious asymmetry: the physical world to which the ensemble of organisms, O was so beautifully adapted, has changed, but the organisms have not: species are fixed and immutable. Figure 1. B can also be taken as representing a phase in Lyell's thinking: a dilemma that emerged from the rapid increase in fossil evidences of extinction, in biogeological evidences of repeated changes in habitat, and in geological evidences of a physical world perpetually changing over long periods of time during the first three decades of the nineteenth century. Taken together, these new ideas undermined the belief in perfect adaptation of immutable organisms to an unchanging world ordained for them. Lyell responded to this theoretical situation in three main moves. First, he allowed a limited amount of adaptive

2. This way of presenting the main outlines and internal relationships of a belief system bears some resemblance to the work of Woodger (1952).

change in organisms in response to changes in their physical milieu—but only within strict limits that did not violate species boundaries. Second, he stressed the accumulation, over untold centuries, of extinctions of organisms no longer suited to their world. Third, to fill the void thus created, he adopted the hypothesis of multiple creations; from time to time, by an unspecified process (but one violating the principle of uniformitarian change), the Creator replenished the natural order by making new, well-adapted species. For a time, probably in late 1835 and early 1836, Darwin entertained this hypothesis of multiple creations, which is represented in of Figure 1. D.

It is striking, however, that this was a delayed reaction on Darwin's part. In 1835, he was more concerned with the special idea sketched in Figure 1. C: organisms *contribute* to the changes in their physical milieu. He worked out a brilliant and successful theory of the formation of coral reefs through the interactions of the growth characteristics of the coral organism and protracted geological changes in the level of the ocean floor. Darwin was only twenty-four years old, but he drew a long theoretical bow. The theory was an original synthesis of geological, geographical, and zoological knowledge. It employed thought forms about population limits and about equilibration processes that reappeared in his theory of evolution through natural selection some three years later. It should also be noted that this theory was *opposed* to Lyell's own theory of coral reef formation. Thus, although Darwin was enthusiastic in adopting various mentors, he was able to maintain sufficient freedom of thought to go his own way when necessary.

Figure 1. D illustrates the hypothesis of multiple creation. Elsewhere (Gruber, 1981), insufficient attention was given to this transitional phase. The subsequent publication of Darwin's *Red Notebook* has made it possible to rectify this neglect.[3] In that notebook, Darwin recorded his ideas at the end of the voyage and shortly after, during the months just before beginning his more celebrated *Transmutation Notebooks*.[4]

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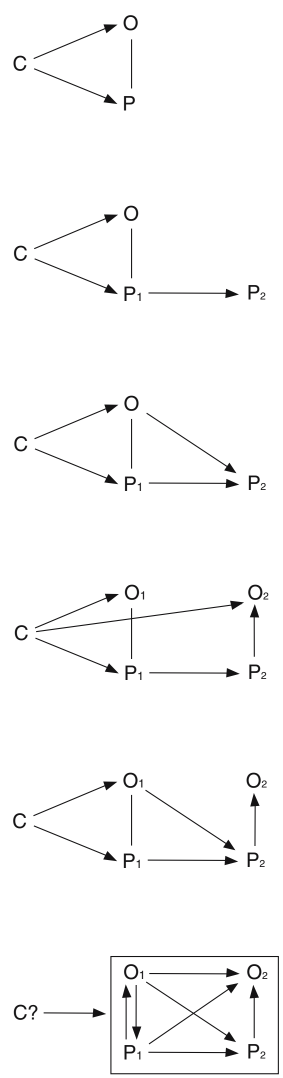
3. *The Red Notebook*. A miscellany of notes, mostly on geological subjects, but containing some of Darwin's earliest postvoyage thoughts on evolution. Published as Herbert, S., editor. *The Red Notebook of Charles Darwin*. Ithaca and London: British Museum (Natural History) and Cornell University Press, 1980.
4. *The Transmutation Notebooks*. Darwin labeled The First Transmutation Notebook B, the Second C, the Third D, and the Fourth E. Published as de Beer, G., Rowlands, M.J., and Skramovsky. B.M., editors. *Darwin's Notebooks on Transmutation of Species*, Parts I-IV, Bulletin of the British Museum (Natural History Series,), vol. 2, nos. 1-6, 1960-1961; Part VI, same journal, vol. 3, no. 5, 1967.




A. 1832 and before: The Creator has made an organic world (O) and a physical world (P); O is perfectly adapted to P.

B. 1832-1834: The physical world undergoes continuous change, governed by natural laws as summarized in Lyell's *Principles of Geology*. In other respects, B resembles A.

C. 1835: The activities of living organisms contribute to the evolution of the physical world, as exemplified by the action of the coral organism in making coral reefs. In other respects, C resembles B.

D. Late 1835. The Creator replenishes the earth's stock of organisms with new species from time to time: the arrow $CO_2$ represents this hypothesis of multiple creation. Organisms also change to adapt to changing circumstances ($P_2 0_2$), but such adaptive changes never produce new species.

E. 1836-1837: Changes in the physical world imply changes in the organic world, if adaptation is to be maintained: the direct action of the physical milieu induces the appropriate biological adaptations. In other respects, E resembles C.

F. 1838 and after: The physical and organic worlds are both continuously evolving and interacting with each other. The Creator, if one exists, may have set the natural system in being, but He does not interfere with its operation, standing *outside* the system.

*Figure 1.* Six phases of Darwin's changing world view

In the *Red Notebook*, the occurrence of this additional phase becomes much clearer than in other documents. It should be noted that Figure 1. D shows a system that is symmetrical at the level of substance but not at the level of process. Under this system, new creations replenish the natural order of living things, but the physical world changes through the operation of uniform, knowable, natural laws. The organic world is replenished by some mysterious intervention quite different from ordinary reproduction.

In Figure 1. E Darwin is going his own way. In a sense, the causal relationship, $P_2$———$O_2$ is only an extension of Lyell's ideas. But as representing Darwin's thinking, $P_2$———$O_2$ means the production of new species by natural processes, of "breaking the species barrier," an idea that Lyell vigorously opposed. This was not a decision Darwin reached quickly. It took the postvoyage processing of the Beagle collections by a number of zoologists to produce Darwin's full "conversion" to the idea of evolution. This probably took place in late 1836 and early 1837. Only then was Darwin free to begin exploring the domain of possible evolutionary theories indicated very roughly in Figure 1. D and E.

The empirical evidence was by no means sufficient to effect the conversion. Indeed, the team of experts on whom Darwin relied for the clearest formulation of the evidence was not all disposed to think as evolutionists. It took all the other factors mentioned previously to create in Darwin the special point of view and schematization of nature into which these new facts were assimilated.

The development just described, in very shorthand fashion, takes Darwin from about the end of 1831 to the end of 1836, the five years from the ages of twenty-two to twenty-seven. Some time early in 1837, he began to commit himself seriously to the task of developing a workable theory of evolution. He made some notes on this in the *Red Notebook* mentioned previously and began the celebrated *First* (of four) *Transmutation Notebook*, also known as the *B Notebook*, in July 1837. For the fifteen months that followed, we have been able to trace the phases of his evolutionary theorizing. It is not possible to give an exact count of the number of phases. Embryonic theories are often ephemeral, and competing ideas can be entertained simultaneously. Moreover, different scholars dissect and reconstruct the protocol somewhat differently. In spite of these difficulties, it is safe to say that there were about five major theoretical phases during the fifteen months preceding his reading of Malthus' *Essay on Population* on September 28, 1838. He then achieved a reasonably clear insight into the idea of evolution through natural selection.

This was not a fallow period. Darwin was not lying in wait for the one great insight. Rather, there were many insights, possibly as many as one or two each day (Gruber 1981e). Nor can it be said that the supposedly great insight was recognized by Darwin as qualitatively different from all the others. His behavior belies that notion since he simply went on with various preoccupations much as before. Thus, the point at which he had arrived on September 28th was by no means a terminus. He had still to see the pertinence of the model of artificial selection as a sort of microcosm of natural selection. He had still to extend the idea of natural selection to mental evolution (Richards 1981). He had still to solve the baffling problem of evolutionary divergence (Browne 1980). He had to come to terms with the unsolved problems of hereditary change and transmission and to construct a theory that detoured this whole intractable subject. These and other problems occupied him during the rest of his life.

There were no perfectly satisfactory answers to most of these questions. He had to learn to live with considerably more theoretical uncertainty than his Newtonian aspirations prescribed.

Each of these developments would require considerable time and space to elaborate. Indeed, the list of problems to be faced has been much shortened and simplified. Perhaps enough has been said on the subject to establish the idea that growth of a belief system is extraordinarily complex, which probably helps to explain why it is often such a protracted process (see, for example, Westfall (1980a) on Newton; Wertheimer (1945) on Einstein).

Before turning to the next major section of this chapter, there are three remarks on methodology to be made. First, Darwin's intellectual development is extraordinarily well documented by the literally thousands of pages of private notes he kept, often in dated sequences. In spite of some differences in interpretation, there is a remarkable degree of agreement among Darwin scholars looking at the same material. Second, a developmental approach, watching the process of thought as it moves through time and seeing it in its historical context (both in the sense of social history and in the sense of the more internal history of science), is often extremely helpful in understanding the material. This is particularly true where interpretation does not spring immediately to the eye.

Third, the abandoned theories were neither useless mistakes for Darwin, nor were they merely way stations on the road to the definitive theory. It is more plausible to suppose that they all served, while they were active beliefs, as tools for organizing what might be called *units* of knowledge and thought. And since they all belong to the same general family of theories, a unit developed in one context often turns out to remain serviceable as theoretical work moves on. Up to this point, researchers have been so absorbed in the difficult task of reconstructing the theoretical steps as distinct and describable structures of belief, that the elaboration of the constructive functions of theories while they last has often been neglected.

### *Organization of Affect*

The second great subsystem of the creative mind at work is the organization of affect. Psychologists have relatively little to say of consequence about the affective lives of creative people at work. Far too much attention has been given to negative affects—anxiety, guilt, rage, fear, and so on. Psychological inquiry seldom asks about such things as courage or the joy of discovery. Such positive emotions are the ones most relevant to the understanding of creativity at work.

Moreover, psychologists have paid little attention to the way the affective side of experience is patterned and orchestrated over time. Almost everything written about affect treats the person as though he or she has one affect at a time, or perhaps a conflict of two. But an affective experience can be seen as something like a musical experience, such as a sonata or a symphony. When such an event is experienced, it has phases in which different emotions are evoked and the patterned relations among these phases makes the whole what it is. The joyful surprise ending of the Beethoven violin concerto would not be same without the suspenseful, quasi-repetitious buildup. Such feelings are prominently exhibited in a passage Darwin wrote when he was twenty-three years old. Not only does he describe a complex, on-going experience, he also consciously anticipates a different affective pattern for a later time. From various autobiographical allusions in his later writings, such as the *Origin of Species*, we can see that this anticipation of a future affective life was paralleled by recollections of the past. An emotional experience, then, can be both extended in time and rich in a given moment.

During the voyage of the Beagle (1831-1836; ages 22-27), Darwin kept a diary that was posthumously published (Darwin 1934). Early in the Diary, he wrote one of a number of ecstatic passages about the beauty of nature and the lushness of tropical forests. This love of, and dwelling on, sensuous experience was richly represented in Darwin's life. It was in a sense overdetermined since it combined elements drawn from his grandfather's poetry, from the nature prose and poetry of the day, from his formal education by naturalists, and from his own years of boyhood and adolescence spent in field work. When thinking of someone like Darwin, who was doing all of the more abstract things that entered directly into his theoretical efforts later on, the affective sensuous components must also be remembered.

Early in the voyage, Darwin wrote in his Diary:

> About 9 o'clock we were near to the coast of Brazil; we saw a considerable extent of it, the whole line is rather low & irregular, & from the profusion of wood & verdure of a bright green colour. About 11 o'clock we entered the hay of All Saints, on the Northern side of which is situated the town of Bahia or San Salvador. It would be difficult [to] imagine, before seeing the view, anything so magnificent. It requires, however, the reality of nature to make it so. If faithfully represented in a picture, a feeling of distrust would be raised in the mind, as I think is the case in some of Martins' views. The town is fairly embosomed in a luxuriant wood & situated on a steep bank overlooks the calm waters of the great bay of All Saints. The houses are white & lofty & from the windows being narrow & long have a very light & elegant appearance. Convents, Porticos & public buildings vary the uniformity of the houses: the bay is scattered over with large ships; in short the view is one of the finest in the Brazils. But these beauties are as nothing compared to the Vegetation; I believe from what I have seen Humboldt's glorious descriptions are & will for ever be unparalleled: but even he with his dark blue skies & the rare union of poetry with science which he so strongly displays when writing on tropical scenery, with all this falls far short of the truth. The delight one experiences in such times bewilders the mind; if the eye attempts to follow the flight of a gaudy butter-fly, it is arrested by some strange tree or fruit; if watching an insect one forgets it in the stranger flower it is crawling over; if turning to admire the splendour of the scenery, the individual character of the foreground fixes the attention. The mind is a chaos of delight, out of which a world of future & more quiet pleasure will arise. I am at present fit only to read Humboldt; he like another sun illumines everything I behold (Darwin 1934).

Notice Darwin's (literally) glowing reference to Alexander von Humboldt, who had been his hero for about two years but was soon to be replaced by Charles Lyell. The relationship between Lyell and Darwin later grew into a mature and abiding friendship, and I do not think that Darwin found or sought another hero.

Charles Darwin was not very close to his father, Dr. Robert Darwin, an imposing and eminent physician. Instead, he found a succession of "father figures": the zoologist, Professor Robert Grant at Edinburgh University, the botanist, Professor John Henslow at Cambridge University, the entomologist, Professor Hope in London whom Darwin once addressed as "my father in entomology," and of course, Humboldt and Lyell. But it should be noted that none of these was the kind of father figure whose influence pervades and dominates the whole of life. Rather, each was an intellectual and scientific collaborator appropriate to one or another of Darwin's scientific purposes. Even his own father would eventually play this role. In the *M and N Notebooks on Man, Mind, and Materialism* (1838-1839),[5] Darwin drew greatly on his father's store of medical and psychological knowledge. In the opening passage of the *M Notebook*, Darwin records certain observations his father had made about the intercorrelations among both physical and mental hereditary traits, beginning the notebook with the words, "July 15, 1838. My father says ..."

Notice also in the Diary passage reproduced previously Darwin's sense of futurity, "I am at present fit only to read Humboldt ..." but he was to develop as a person. "The mind is a chaos of delight, out of which a world of future and more quiet pleasure will arise."

At this early point in the voyage, he had not gained much momentum in developing a clear-cut set of purposes to guide him in his work. However, he already had some sense of the relation between the voyage experiences to come and his emerging sense of self.

The uniformly positive tone of this passage characterizes the early part of his Diary and his other writings. Then the tone changes. Another note is introduced. Darwin had a lot of experience with death during the voyage. There was the death of a shipmate. There was his direct observation of the wars of extermination conducted by the Spaniards against the Indians of South America. There was his intuitive sense of a changing balance of life and death in different regions he visited. After his first enthusiastic encounter with the luxuriant tropical scenery of Brazil, he visited that bleak southernmost tip of South America, Tierra del Fuego. There he wrote "... here things are different because death predominates, as compared with life." Figuratively, this

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5. The Notebooks on Man, Mind, and Materialism. Darwin labeled these two M and N. Chronologically, they overlap *The Transmutation Notebooks*. The latter span the period from July 1837 to some time in 1839. The M and N Notebooks were begun on July 15, 1838 and continue until some time in 1839. Published in Gruber, H. E. and Barrett, P. H. *Darwin on Man: A Psychological Study of Scientific Creativity Together with Darwin's Early and Unpublished Notebooks*, New York: Dutton, 1974. Reprinted separately as Barrett, P. H., editor. *Metaphysics, Materialism, and the Evolution of Mind. Early Writings of Charles Darwin with a Commentary by Howard E. Gruber*. Chicago: University of Chicago Press, 1980.

expression captures the bleakness of the place. Theoretically, it could not be true in a stable, living ecology where life and death must always more or less balance out. Later, Darwin came to make this very point a premise of his mature theory.

The *balance* between life and death is sometimes forgotten by social scientists exploiting Darwin's theory. There is a kind of differential uptake of ideas, overemphasizing the selective, decimating aspect of the theory—winners survive, losers die off. But there is also a positive aspect that is equally important. Darwin expressed this duality in the famous closing passage of the *Origin*, in his image of the tangled bank. This pictures the same "chaos of delight" that he wrote about in 1832, but in 1859 explosive growth and differentiation and wonderful variation and diversity vie in importance with the war of nature.

Perhaps the first really trenchant summary of the affective sense of ideas occurs in Darwin's *Fourth Transmutation Notebook*. It can be found in the entry for March 12, 1839, an early evocation of the image of the tangled bank. He wrote: "It is difficult to believe in the dreadful but quiet war going on (in) the peaceful woods and smiling fields—we must recollect the multitude of plants introduced into our gardens ... we see how full nature, how finely each holds its place" (E Notebook, p. 114). It is noteworthy that this imagistic coming into affective awareness occurs almost six months after his first clear insight into the principle of natural selection. At that time, September 28, 1838, the pairing of struggle and change, death and innovation was expressed, but in a triumphant vein—Darwin was solving an intellectual problem and feeling good about it. In the March 1839 entry something is added—the note of sadness at this aspect of nature.

Over long periods of time, there is in Darwin a repeated pattern of affective change. An idea expressed first in a positive problem-solving spirit is reiterated with a note of chastening and sadness added. I have come to think that it would be hard for someone to develop mature, disciplined thought without contending at some point(s) with the finitude of life and the realization that problems are only solved in a definitive way inside finite contexts. This brings the thinker up against the idea of personal death. Understanding that there are such limits, and yet, that in some sense they can and must be transcended by the whole cycle of birth and death and reproduction—this is an important part of the story of one's growth as a thinking person. Another example is Piaget's prose poem, *La Mission de l'Idée*, written in 1915 when he was nineteen, in which the young man struggles with the issue of transcending personal finitude (Piaget 1916, 1977a).

When Darwin began his *Transmutation Notebooks* in July 1837, a question that preoccupied him in the first five pages was just that. He asks, "Why is life short, why such high object generation?" (B Notebook, p. 2). In other words, what is the function in the entire system of living things of the death and reproduction of individuals? And his answer is: to make way for the possibility of adaptive change. The living system must be kept open and plastic; changes that cannot occur in a mature individual can, through one means or another, occur in an infant creature or during conception. The details of the theory that he was then elaborating are complex and interesting.

But at present I want only to draw attention to the fact that there is a connection between this affective change of coming to terms with birth, life, and death and the actual theoretical system he was constructing. The same connection is poignantly expressed in his very personal notes of *Marriage*, written in 1838, just before his marriage to Emma Wedgwood (see Darwin 1958, also Keegan and Gruber 1983).

It is reasonable to speak of a set of affective transformations in Darwin that correspond to his intellectual development. The youth is willing to lend his services as a field naturalist and collector to a superior breed of scientific specialists. He then becomes both a specialist himself and a wide-ranging, powerful theoretician, directing and exploiting the work of others—keeping them in the dark about his ultimate purposes. The hopeful lad, with an exalted view of nature as God's handiwork, comes first to see it as the product of natural law and then to temper the unalloyed positive tone of his earlier reactions with thoughts of finitude, war, and death. The open, cheerful student ready to share his thoughts with all comers, begins to realize that he must keep some of them to himself. First, in his long encounter with the *Beagle's* captain, Robert Fitzroy, and later, as he pursued a theory of evolution, he saw that the public world of science would exact a price for revolutionary violation of its norms. To contend with these dangers, purposeful, strategic planning would be necessary. "Mention persecution of early astronomers," he instructs himself in the spring of 1838 (C Notebook, p. 123).

At this point Darwin seems still to have intended an open avowal of his beliefs. He wrote, "Love of the deity effect of organization, oh, you materialist! ... Why is thought being a secretion of the brain, more wonderful than gravity a property of matter? It is our arrogance, it (is) our admiration of ourselves" (C Notebook, p. 166, written about May 1838). But only a little later the prudential plan of more limited expression of his ideas begins to emerge: "To avoid stating how far I believe in Materialism, say only that emotions, instincts, degrees of talent, which are hereditary, are so because brain of child resembles parent stock" (M Notebook, p. 57, written about August 1838). He hoped to steer between the Scylla of theology and the Charybdis of blasphemy. As he came closer to the moment of insight of September 28, 1838, he had a dream of being executed for his wit. But as in the later reality of his life, so in the dream. The martyr does not flinch; he keeps his thinking mind intact until the very moment that he loses his head. And he does come back to life. Just so, Darwin's ideas lay dormant and concealed; then they were brilliantly expounded in the *Origin* and twelve years later in the *Descent of Man*. They survived bitter attacks and prevailed.

I have been criticized (Richards 1981) for arguing that Darwin's double delay (first in publishing the *Origin* and second in revealing his views on man in *Descent*) was due to his fear of persecution and ridicule. Exclusively "cognitive" historians of science have insisted that the intellectual difficulties Darwin faced were great enough to account for his hesitancy in publishing. In a sense, I agree. Of course, if he had had a complete and unassailable theory, he could have forged ahead without fear of criticism. But great new syntheses are rarely, if ever, complete and invulnerable. And they are rarely, if ever, advanced in an open, welcoming, and friendly forum where no Establishment stands guard over its vested interest, defending the ideology that justifies its existence. Imperial Britain was then probably an even more repressive society than has yet been brought to light. Darwin's delays were a joint function of his fears of ridicule and his hopes that he would master the unsolved problems of his theory. Directed, purposeful thinking goes on in a feeling person, and Darwin certainly was that.

It was mentioned earlier that Darwin's case is extraordinarily well documented. This cannot be said about his affective development with as much force as about his theoretical work. In his scientific notes, even when he drew on his personal experience, he was not writing in a confessional spirit. Nonetheless, as we begin to look at his letters, notes, and autobiography with his affective development in mind, we see that the record is by no means scanty.

### *Organization of Purpose*

As the third subsystem, the organization of purpose is a general motivational system of a goal-directed person that can be thought of in at least two ways. On the one hand, there is a set of purposes: the tasks, problems, projects, and enterprises that he or she intends to carry out. On the other hand, there may be some underlying motives, conscious or unconscious, that govern the construction and reconstruction of this set of purposes.

A description of the purposes of creative workers requires (1) some scheme broad enough to encompass a varying number of purposes in different sorts of relationships with one another and (2) some scheme that shows the variation over time of the pattern of activities connected with these purposes. I refer to this pattern as a *network of enterprise*. "Network" because the activities expressing the purposes are complexly interrelated; "enterprise"—rather than task, problem, or project—in order to capture the idea that each activity in question may have no fixed end point. It often includes a scheme for replenishing itself with new tasks if ever the original stock nears completion.

The diverse activities comprising the strands of a person's network of enterprise have all sorts of dynamic relations with each other. The concept, network of enterprise, allows for an enlarged view of what psychologists have previously considered under the heading of *intrinsic motivation* or of *task-oriented behavior* (Lewin 1935). What is new in the present discussion is the life-history approach that assumes that the creative person generally chooses his or her goals and constructs his or her network of enterprise. Furthermore, it is my intention to describe neither one such intrinsic motivation at a time, nor a conflict between two, but rather, the operation of an entire, complex, long-lasting network.

The dynamic properties of this network of conscious, task-oriented purposes are not offered as a substitute for the dynamics of the unconscious and ego-oriented motives. Nevertheless, it will be seen that the network of enterprise offers an alternative to the notion that the rich dynamics of behavior lie solely below the surface of consciousness.

In speaking of the long-range goals of a person engaged in creative work, some such concept as general direction is needed. Since the goal cannot be specified exactly, and is rarely attainable in a single step, we must either adopt (Koestler 1959) image of the "sleepwalker" or assume that the creative person evolves some strategies for knowing when he or she is moving in the intended general direction.

Some facets of Darwin's network of enterprise will now be discussed. No one will contest the general idea that by the time Darwin began his *Transmutation Notebooks* in July of 1837 he fully intended to elaborate and defend some theory of evolution. But what can be said of his earlier development? To what extent can his early work and growth be considered "purposeful"? It is not, of course, suggested that Darwin knew his end point, or his intellectual destination, when he began the voyage. Nevertheless, the events that shaped his life did not just happen to him. He participated in the making of his own milieu. His prevoyage and early-voyage scientific literary hero was Alexander von Humboldt. This was Darwin's choice. Even his coming to rely on Lyellian theory must be seen as involving a large element of independent choice. He had an extensive geological library on board the *Beagle* and other theoretical approaches were available that harmonized better with his university training. In going beyond Lyell, in his work on the theory of coral-reef formation, Darwin was independently breaking new ground. As I have shown, elsewhere, he was developing the thought forms of an equilibration model that would later reappear in the theory of evolution (Gruber and Gruber 1962; see also Ghiselin, 1969). So, although we cannot speak of a fixed goal, it is not implausible to speak of intentional movements in a direction even in Darwin's early period.

Here a commonplace but false picture must be corrected. It is the idea that Darwin, when he went to Cambridge, or when he began the *Beagle* voyage, was a rather purposeless, flighty young man, and that it took the luck of bumping into Henslow, his teacher, or the luck of being (the last to be) chosen as the naturalist for the voyage, to start him on his career. That would mean, for our developmental picture, that by the age of eighteen or twenty-one, depending on which version of that story you believe, Darwin was a kind of nobody, and not even a very bright nobody in most versions of the story. This legend is a little implausible. It is akin to the mythology of sudden great insights, rather than slow growth processes, as the major characteristic of creative lives.

As a matter of fact, the story is entirely wrong. It appears that Darwin had a long and rich history of being very purposeful. The purposes in question were not precise, long-range, theoretical goals, but rather the more general kind—to work at a series of projects all contributing to the making of a scientist. When his older brother, Erasmus, went to Edinburgh University, he wrote detailed letters to Charles, carefully outlining the steps necessary for the completion and operation of their mineralogy laboratory. When Charles went to Edinburgh, he immediately joined a student scientific group, the Plinian Society. Material from papers that he read there on invertebrate organisms was included in papers published by his teacher, the zoologist (and Lamarckian), Professor Robert Grant.

At Cambridge, before he met Henslow, Darwin quickly became engrossed in collaborative work on entomology, especially the collection of beetles, together with his cousin, William Darwin Fox. Although they later went separate ways—Darwin Fox to marriage and the ministry, Charles to sea and science—they kept up a lifelong correspondence, often referring nostalgically to their youthful entomologizing. This relationship is a good example of the kind of brotherly cooperation that is often a part of scientific work. There was a great deal of collaboration among peers in the whole Darwin story. Let these few examples stand for the many in his life.

Darwin met Professor Frederick W. Hope, a distinguished London entomologist, at a dinner party. This began a relationship of mutual admiration of collections, exchanging specimens, and field trips together. Young Darwin was a serious, nearly professional entomologist. He could learn from and work with peers and older friends. Then he met a botanist, the Reverend Professor John Henslow, and became known at Cambridge as "the man who walks with Henslow." Like other English worthies, the latter was a clergyman, a professor, and a working naturalist. For a time, Darwin entertained the plan of emulating his mentor's career.

So, Darwin was a very purposeful young man. Of course, his purposes were changing and evolving. To say that he was considering the ministry bears some explanation. A country parson functioned, among other things, as something like an agricultural county agent in our country. As the educated man in the community, the parson brought new knowledge to the farmers around. Darwin had some excellent models to follow, like the celebrated Reverend Gilbert White of Selbourne, or his own friend, Leonard Jenyns, who later became the parson at Swaffham Bulbeck, not far from Cambridge. These men and others like them were virtually professional naturalists as well as productive writers whom Darwin could hope to emulate in thinking of himself as a parson cum natural historian in that "world of future and more quiet pleasure." Although I do not think that Darwin was a deeply religious man, there was no conflict between being religious and having an evolving sense of purpose as natural historian and scientist. Nor was the *Beagle* opening quite as accidental as it is usually painted. Before the *Beagle* opportunity came along, Darwin was himself organizing a voyage of scientific discovery. It was to be a voyage to Teneriffe, an island of special interest to naturalists and also of special symbolic value. In earlier times, the peak of Teneriffe had been thought the highest in the world, a meeting place of heaven and earth. Milton had written of it in *Paradise Lost* (Darwin's constant companion during the *Beagle* voyage). In 1831, Darwin had been recruiting people to go with him on his voyage. He had been down to the docks in London, investigating the price of chartering a ship. He had been studying Spanish. Professor

Henslow was one of his recruits, somewhat reluctantly because he had been recently married. Henslow was relieved when the *Beagle* opening came along, so he could send Darwin off on that adventure instead.

A sense of purpose has a long slow growth, which in Darwin's case probably began in quite early adolescence. There are two early moments when we can see Darwin working out his personal agenda. Written six years apart, the notes in question have one pleasant human feature—a clear-cut division between intellectual interests and concern for creature comforts, with some attention given to each. On board the *Beagle*, but before it weighed anchor and sailed away from Plymouth, Darwin drew up a plan of work:

> *December 13th.* An idle day; dined for the first time in Captain's cabin & felt quite at home. Of all the luxuries the Captain has given me, none will be so essential as that of having my meals with him. I am often afraid I shall be quite overwhelmed with the number of subjects which I ought to take into hand. It is difficult to mark out any plan & without method on shipboard I am sure little will be done. The principle objects are 1st, collecting, observing & reading in all branches of Natural history that I possibly can manage. Observations in Meteorology, French & Spanish, Mathematics, & a little Classics, perhaps not more than Greek Testament on Sundays. I hope generally to have some one English book in hand for my amusement, exclusive of the above mentioned branches. If I have not energy enough to make myself steadily industrious during the voyage, how great & uncommon an opportunity of improving myself shall I throw away. May this never for one moment escape my mind & then perhaps I may have the same opportunity of drilling my mind that I threw away whilst at Cambridge. (Darwin 1934)

These are the resolutions of a young man who has not yet found a very clear sense of direction other than the very broad ones of being an educated man and a naturalist. This impression is borne out by the scientific notes of the first year or so of the voyage.

Six years later in London, contemplating marriage, we see him in full stride, knowing where he is going intellectually. In quick succession, he writes two notes to himself about the pros and cons of marriage. In the first, the varied strands of his network of enterprise are remarkably visible. Marriage will interfere with travel, that is, with field geology. But staying put will permit work on "transmutation of species," on "simplest forms of life," on "physiological observations on lower animals," and speculations on geographical distribution of organisms. Marriage will necessitate earning a living: "Cambridge Professorship, and make the best of it ..." He is planning not just his work, but his life and work. *And he knows what be wants to do* (Darwin 1958).

In the second set of notes, he outlines the desirable emotional and social conditions of life: "Only picture yourself a nice soft wife on a sofa and a good fire, and books and music perhaps ..." *He knows what he wants to feel.*

The problem he confronts in writing these marriage notes is to organize a life that will be physically and emotionally comfortable enough, without deflecting from his chosen course. The solution he was nearing was his marriage to his cousin, Emma Wedgwood. The notes conclude ... "Marry–Marry—Marry Q.E.D." The conclusion of this passage, "Q.E.D.," means *Quod Erat Demonstrandum*, the traditional closing of a successful mathematical proof. Darwin's choice of terms underlines the explicit problem-solving spirit in which he approached the organization of his life. These notes have not been dated exactly, but were probably written in the summer of 1838. On November 11, 1838, Darwin proposed to Emma Wedgwood. They were married in January 1839, and their first child, William, was born before the year was out.

Meanwhile, his scientific agenda were also rapidly developing a new shape. On July 15, 1838, he began his notebooks on man, mind, and materialism. The reasons for this major branching in his network of enterprise have been thoroughly discussed elsewhere (Gruber 1981e). Here, two simple points can be made. First, between the decision to begin these notebooks and the decision to write the *Descent of Man*, thirty-six years elapsed. Moreover, after William was born, Darwin kept a diary of observations on the growth of intelligence and of the emotional life of his baby. The material from this diary was published in his paper, "A Biographical Sketch of an Infant" thirty-seven years later. *Enterprises endure*.

Second, as mentioned earlier, Darwin was particularly cautious about revealing his views on human evolution. Between the publication of the *Origin* in 1859, in which he said almost nothing about *homo sapiens*, and the publication of the *Descent* in 1871, twelve years elapsed. *Enterprises need not be public*.

Darwin functioned over long periods of time as though he had a conscious but private agenda. He brought different parts of his work to the public in a highly controlled, strategically regulated way (see Gruber (1981e) and Rudwick (1982) for further discussions of this point). The geological material surfaced first, the evolutionary material next, and the material on man and mind last.

## THE MOVEMENT OF THOUGHT

In this last section, the general movement of Darwin's thought in the period from 1831 to 1839, the voyage of the young naturalist and the few years after, will be characterized. His scope was expanding, moving from being a collector and a describer to being an original theoretician. The scope of his theoretical work expands from rather narrow-gauge hypotheses, for example, about the geology of a region, to far-reaching and well-grounded ideas about the geology of the earth as a whole. Over a period of about two years, he studied the elevation of the mountains of South America. He then saw that a conservation principle must apply: If the figure of the earth is to remain approximately spherical, then there must be a compensatory relation between elevations and subsidences. This hypothesized pattern characterized not only the continents, but also the whole sea bottom of the Pacific Ocean. If such a pattern continues over many years, then there must be corresponding changes in another set of possibilities: the forms of life that can exist in particular places, depending on the depth of the ocean. His whole theory of the formation of coral reefs is based on this notion of cycles of elevation and subsidences. In other words, it is grounded in a conservation principle applied on an enormous scale in a very deliberate way. Part of the originality of this scheme is its breaking down of the distinction between continents and oceans.

The question of scale must be examined carefully. If elevation represented a really big bulge, the figure of the earth would not be conserved. But even the difference, in distance from the center of the earth, between the highest mountain and the lowest sea bottom is only some ten miles or about two-hundredths of a percent of the radius. Compensation rules, then, can apply, keeping the earth approximately round.

This change in scale and its consequences for the very shape of theory are reflected in one striking autobiographical passage in the *Origin*. Beginning with the personal marker, "When a young naturalist ..." Darwin goes on to describe the series of dilemmas confronting the young scientist who starts out with a system of classification based on a restricted region (for example, England) and encounters seeming anomalies as his exploration expands to larger and larger regions (for example, the world circumnavigated in the *Beagle* voyage). [His "difficulties ... rise to a climax" (Darwin 1859, 50).] The solution must be something beyond mere tinkering with the system of classification: "community of descent is the hidden bond which naturalists have been unconsciously seeking, and not some unknown plan of creation or the enunciation of general propositions and the mere putting together and separating objects more or less alike" (Darwin 1859, 420). Thus, theory moves from classificatory to causal models and theorizing pushes out to wider and wider domains reaching for the limits of space and time.

Although this growth in scale, scope, and depth in Darwin's thinking during the voyage can be seen, no great degree of reflectivity about the way in which the work of science is to be done is apparent. At the very end of the voyage, there are but a few pages of notes on this subject. During the voyage, and also in the *First Transmutation Notebook*, there is a kind of work that might be characterized as direct scientific thinking. There are problems, and those problems are thought about. In the *First Transmutation Notebook*, there is a certain amount of what may be called metascientific thinking, but only a sentence or a phrase here and there, almost tossed off. By the *Second Notebook*, however, some six months into the process of thinking about theories of evolution, there is a rather sharp rise in the amount of metascientific thinking. It is not so much that the frequency of his references to various types of problem rises, but each allusion, when it does occur, tends to be longer—a paragraph or even a page in length, rather than a phrase or a sentence.

The end of the *First Notebook* and the whole of the *Second Notebook* are studded with such remarks. There are strategic thoughts; for example, specific genealogies of species are not traceable in fine and continuous detail (C Notebook, 64)—but enough can be seen to support ideas about the laws of change. Thus, Darwin remarks "... the one end of classification [is] to express relationship & by so doing discover the laws of change in organization" (C Notebook, 158).

He is expansive and hopeful about finding such laws: "The grand question which every naturalist ought to have before him when dissecting a whale or classifying a mite, a fungus, or an infusorian, is What are the Laws of Life?" (B Notebook, 229). He welcomes the speculative attitude in a kindred spirit: "Lamarck ... had so few clear facts, but so bold ... was endowed with what may be called the prophetic spirit in science. The highest endowment of lofty genius" (C Notebook, 119). He is frequently critical of anthropocentrism and—perhaps contradictorily—cautiously receptive to the idea of evolutionary progress, a topic which he recognizes as belonging in the domain of "metaphysical speculations" (C Notebook, 104). He waxes metaphorical on numerous occasions, and he reflects more analytically on the role of analogy in science (C Notebook, 138-40).

Explicit metaphysical ideas sprout up here and there: "Love of the deity effect of organization, oh you materialist!" (C Notebook, 166). "There is one living spirit prevalent over this world ... which assume a multitude of forms ... according to subordinate laws. There is one thinking sensible principle intimately allied to one kind of organic matter..." (C Notebook, 210-11).

Why this rise in metascientific reflectivity? Three reasons are now suggested. First, Darwin was living in London, bombarded with the new findings and controversies of a vigorous scientific community, stimulated by many personal contacts with other scientists (Rudwick, 1982). He had had several years of practice and received a good share of recognition for theoretical work in a related field, geology. Second, he had by then explored a domain of possible ideas fairly thoroughly, reached both a sort of intellectual plateau and a reasonably successful integration of a wide variety of facts and restricted laws, under the general premise of evolution. He was looking for a still higher level of theoretical integration. Third, and most important, he was baffled. This is difficult to document, but it seems to me that when he began the *First Notebook*, he felt he was on the track of (if not in possession of) a viable theory and that this feeling persisted for some time through a number of theoretical changes. But the *Second Notebook* seems more exploratory, and there is no clear sense of direction or specifiable theory that he is working out. One possible objection to this hypothesis of bafflement leading to reflectivity is the very positive upbeat tone of his writing. But bafflement need not be accompanied by depression. Life was going well for him and, on the theoretical front, he was certainly not defeated.

In the *Third Notebook*, a few clear expressions of this sense of being "stuck" come through. On August 27, 1838, he writes, somewhat ineffectually, "There must be some law that whatever organization an animal has, it tends to multiply & improve on it. Articulate animals must articulate, & in vertebrate tendency to improve in intellect ..." But he goes on to cite a counter example, "Yet fish same as, or lower than in old days ...???" (D Notebook, 49). On September 7, he writes, "Seeing what Von Buch, Humboldt, G. St. Hilaire, & Lamarck have written, I pretend to no originality of idea—(though I arrived at them quite independently ...) the line of proof & reducing facts to law [the] only merit if merit there be in following work" (D Notebook, 69).

It took Darwin some time to assimilate the importance of his insight of September 28, 1838. For several months, he seems to have treated it as just one more promising idea and gone on with his earlier preoccupations and problems. His dream of October 30 suggests that he did not, even then, feel that he had put the whole puzzle together in a satisfying way. He dreamed that he had read a page of a French book, pronouncing each word distinctly, "but could not gather general sense of this page" (N Notebook, 33). In a waking state, he read French often and fluently, so it is reasonable to speculate about the symbolic meaning of this dream of comprehension and to suggest its analogy to the state of his still inchoate emerging theory of evolution.

The idea that Darwin moved toward the principle of natural selection almost from the beginning of his *First Notebook* can be demonstrated. His early branching model of evolution, which assumed differentiation and extinction with the number of species constant, strongly implied a formal (but not a causal) principle of selection. In the fifteen months that followed, he wrote a number of times of phenomena like natural selection but in very restrictive contexts. Even after September 28, 1838, it appears that he was still moving toward the principle, for he had not yet seized and wielded it with consistent vigor. It took a few years for Darwin to extend the idea to the evolution of mind (Richards 1981).

I know that the suggestion that Darwin, or anyone, moved toward an as yet unexpressed idea smacks of teleology, as does any idea of "progress." But I believe that a view of the history and development of human thought without the idea of progress is a doctrine of despair. To be sure, contemporary ideas in developmental psychology are confusing. In Piaget's theory, for example, the stage theory of individual development is modeled on the general idea of progress. But since it is a quasi-embryological theory of universally recurring stages, it entails no progress from generation to generation. On the other hand, Piaget's early romantic writings, especially *La Mission de l'Idée*, and his work in the history of science are imbued with evolutionary thought and a firm belief in the idea of progress. This concatenation of embryological and evolutionary ideas is not necessarily contradictory, but the work necessary to make it coherent has only begun (Gould 1977).

It was mentioned near the beginning of this chapter that intellectual progress does not require the emergence of new operations. However, Darwin's progress suggests that the consolidation of new contents of thought sets up new criteria for next steps. Thus, contents become tools. Moreover, the establishment of new contents sets the scene and opens the way for new undertakings.

Therefore, although Darwin always implicated man in his early evolutionary musings, it was not until he had made sufficient progress on various other fronts that he began the M and N Notebooks (in July 1838). There he made the explorations of the domains of man, mind, and materialism an explicit set of tasks, a new enterprise. This early, very private sequence in his notebooks was repeated in public much later (Darwin 1859; Darwin 1871).

To understand the movement of thought, a concept such as sense of direction is needed. Movement in a direction is one version of the idea of progress. Darwin's life exemplifies movement in the direction of making the implicit explicit and in the direction of demystifying the past. It is our turn to demystify the future.

# Going the Limit: Toward the Construction of Darwin's Theory (1832-1839)[1]

As a cognitive psychologist, my forays into the history of science have as their ultimate aim to contribute something to the psychology of thinking and the psychology of creativity. I hoped to learn from historical studies, and enrich my own rather crabbed, often Philistine field. In the course of this effort, my students and I found ourselves developing what we now call, quite provisionally, an *evolving systems approach to creative work* (Gruber 1980b, 1980g).

In this view, creative work is seen as a purposeful growth process. Much work on the psychology of creativity reveals a certain tropism toward monolithicity. In such diverse ideas as: one great insight, one ruling passion, one overarching metaphor — there is a common term, one. In contrast, our work has persistently revealed a striking pluralism of events and processes. For Darwin there were many insights, each with a complex inner structure; rather than representing a break with his own past, they reflect the ongoing function of the evolving system of thought (Gruber 1981a). Similarly, there are many influences, several candidates for his "father figure," many metaphors (Gruber 1978a), and many enterprises.

In addition to this emphasis on growth and pluralism, we stress the idea of creativity as *purposeful* work. Since it always seems to take a long time, the creative must go to some lengths to organize the conditions of life that make possible such continued work. If it were easier, faster, and more straightforward than experience shows to be the case, spontaneity might be enough. But if it were so easy, fast and straightforward, many would accomplish the same thing, and we would not deem it so creative. In the real world, then, purpose is indispensable for creativity.

The person doing creative work exhibits the continuous interplay of three loosely coupled sub-systems: the organizations of knowledge, of purpose, and of feeling. This interplay is displayed with particular clarity when the thinker undertakes to push ideas to their extremes, to abandon cautious middle-of-the-road strategies and instead to test the limits of his innovations. Sailing to the edge of one's intellectual world does not happen by accident: it requires deep knowledge and a sense of direction. It is, moreover, so taxing an effort that it requires intellectual courage and, if not the ability to enjoy life at the edge, at least the resolve to endure it.

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1. Writing this essay was completed during a stay at the Institute for Advanced Study, whose hospitality I gratefully acknowledge. I thank Martin Rudwick and Doris Wallace for helpful comments. The idea of thought-form is being elaborated in a doctoral dissertation by Robert T. Keegan on Darwin's unpublished "Diary of an Infant."

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The current status of Darwin studies provides an object lesson in the density and complexity of a creative thought process. Instead of being apologetic that we, the collectivity of Darwin scholars, have written so much, we ought to brace ourselves for the probable future. The history and philosophy of science, cognitive science and developmental psychology have reached a promising confluence. The idea that the work of hermeneutic interpretation is a legitimate part of our enterprise has at least taken hold, and description is becoming thicker and thicker. We are, I think, growing more skilled in relating the internal history of science to wider issues in personal psychology and social history. Out of all this will emerge a new generation of Darwin studies, and during its gestation we should all be very patient. Newell and Simon (1972), in their book *Human Problem Solving*, analyze the thinking of one subject solving one problem, thinking aloud while he did it. The subject took twenty minutes. The analysis covers 100 pages.

The study of Darwin's thinking is many orders of magnitude more complex. He was solving not one problem but many. The problems were not chosen for him but by him as part of a broader effort to construct a new point of view. He faced a double task. On the one hand, he had to make the best possible use of a wide array of professionally accepted, normalized scientific knowledge. On the other hand, he had to organize his efforts so as to raise and answer questions hardly dreamt of within that conventional framework. To understand Darwin's thinking, we must study the connections between these quite different aspects of his work—his intellectual navigation in well-charted scientific waters and his explorations of the farthest horizons.

## NETWORKS OF ENTERPRISE

If we are to deal with the complexities of a creative life, we absolutely must develop some methodical ways of surveying it as a whole. As we go deeper and deeper into detail, we need to avoid losing our sense of direction. One orienting device that I have proposed is the *network of enterprise* (Gruber 1977b). This is a diagrammatic way of examining the creative person's organization of purpose by depicting all of the activities of the person as they are connected in time. It permits us to see both the continuity within and the diversity among simultaneous ongoing activities. I use the term *enterprise* to suggest something larger than a problem or project; it has no necessary termination, and the stock of projects within it are usually renewed in order to keep it functional. Of course, at any given time some enterprises are dormant or less active than others.

As it happens, quite independently of my work, Sandra Herbert in her edition of Darwin's *Red Notebook* has published some excellent diagrams that capture the same idea in a simple and illuminating way (Herbert 1980, 14-17). Although a number of colleagues (and I, too) have drawn up networks of enterprise for Darwin, I believe the best reasonably complex diagram currently available was drawn by Martin Rudwick (1982). This was constructed in such a way as to show that Darwin's network was not only a set of activities, but an agenda. More specifically, it was a plan for the sequence in which his different enterprises would rise from the privacy of Darwin's mind to the level of public disclosure.[2] Needless to say, a network of enterprise has other dynamic properties. For example, one enterprise can steer another, distract attention from another, provide thought-forms and metaphors useful in other contexts.

More broadly still, the network of enterprise represents the organization of purpose for the creative person. As such, since he or she is more or less aware of its structure, it is a fundamental part of the self-concept.

In Darwin's case, as the present essay and for that matter this entire volume show, it is indispensable to see each part of his activity in relation to the others. Ideas or actions which seem ambiguous in a narrow context are clarified as the frame is widened. The point is not so much that we the interpreters clarify Darwin's meaning, but rather that we come to understand how Darwin, over time, disambiguated himself.

## THE VOYAGE BEGINS

When Darwin set out in the Beagle, it took him a while to get his sea legs and longer still to find his feet as a professional naturalist moving towards the life in science we know him for. Even then he remained vulnerable to *mal de mer* and to a certain *mal d'esprit* reflected in remarks such as:

> This multiplication of little means & bringing the mind to grapple with great effect produced is a most laborious & painful effort of the mind ... (C75)

During the voyage, alongside his scientific notes he kept a diary of all sorts of narratives and personal feelings (but nothing too intimate to publish in the Journal he may have already been contemplating). There were in the Diary many observations pertinent to what would eventually play a major role in his evolutionary theories, and become a distinct enterprise in its own right—his reflections on *homo sapiens*. A few early entries in this Diary reveal his state of mind, his plans, and some of his basic orientation at the time (Darwin 1934).

On 13 December 1831, two weeks before the *Beagle* weighed anchor, he wrote a brief sketch of plans for work during the voyage.

> I am often afraid I shall be quite overwhelmed with the number of subjects which I ought to take into hand. It is difficult to mark out any plan & without method on shipboard I am sure little will be done. The principal objects are 1st, collecting, observing & reading in all branches of Natural history that I possibly can manage. Observations in Meteorology, French & Spanish, Mathematics & a little Classics, perhaps not more than Greek Testament on Sundays. I hope generally to have some one English book in hand for my amusement, exclusive

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2. Rudwick and I have had a fruitful exchange on the matters covered here. On the relation between public and private science, see also my essay, *The Many Voyages of the Beagle* (1994b).

> of the above mentioned branches. If I have not energy enough to make myself steadily industrious during the voyage, how great & uncommon an opportunity of improving myself shall I throw away. May this never for one moment escape my mind & then perhaps I may have the same opportunity of drilling my mind that I threw away whilst at Cambridge. (Diary, p. 14)

Thomas Huxley, writing his resolutions at a similar stage—the beginning of the voyage of the Rattlesnake—was far more specific and more professionally crisp (Huxley 1935, 16-17). Perhaps Darwin's initial looseness and openness was a great asset, when coupled with certain other attributes.

On January 11, 1832, sailing from Tenerife to Cape Verde Islands, he has been working hard with his marine catches.

> January 11th. I am quite tired having worked all day at the produce of my net. The number of animals that the net collects is very great & fully explains the manner so many animals of a large size live so far from land. Many of these creatures, so low in the scale of nature, are most exquisite in their forms & rich colours. It creates a feeling of wonder that so much beauty should be apparently created for such little purpose. (Diary, p. 23)

Presumably, his nets caught mostly small organisms, so he realizes there is a good food supply for larger ones. Here, then, is Darwin thinking about the food chain, very early. Note also the ease with which he steps back from his own assumption of functional order to enjoy "a feeling of wonder" at the apparent lack of purpose in the beauty of the natural world.

On February 28, 1832 he records his early reactions to tropical scenery (See page 132). Darwin saw himself going beyond his earlier "chaos of delight." His cathexis with nature was deepening. We see Darwin's ability to stand away from the things he admires, and to go beyond the moment. I believe this passage records the moment when Darwin began to construct his metaphor of the "entangled bank," which became the organizing principle of the celebrated closing passage of *The Origin of Species*.

On December 18, 1832 he recorded his first reactions to a primitive group, the Indians of Tierra del Fuego: "I would not have believed how entire the difference between savage and civilized man is. It is greater than between a wild and domesticated animal, in as much as in man there is great power of improvement" (Diary, p. 119). In this and other passages Darwin conveyed his vivid sense of the strangeness of these "inconceivably wild" people. These entries also reveal his commitment to the ideal of progress and show him aware of the vast transformations possible within a species.

## 1832-1834: DARWIN ASSIMILATES LYELL'S PRINCIPLES

Throughout the voyage, Darwin's major activity, by a long margin, was in the field of geology. During the first two years, the main manifest event in Darwin's development was his reading of Lyell's *Principles of Geology* (1830-1833), moving toward the increasingly explicit decision to reject the catastrophist geology he had learned from his teacher Adam Sedgwick, in favor of Lyell's uniformitarianism. Each theory had something to say about physical geology and something to say about the relations among geology, paleontology, and biogeography.

As Hodge has recently emphasized, the theoretical situation in geology then called for systematic search for fossils, with or without benefit of Lyell's *Principles* (Hodge 1982). And we see that Darwin sprang into action on this front early in the voyage. He went out looking for fossils and he made exciting finds. Although there is a clear distinction between the two positions, it is not hard and fast. There are slow processes in Sedgwick's and fast ones, even floods, in Lyell's. There are extinctions in both, and both rely on some mysterious "creation" to replace the lost species.

In the field of physical geology, the matter is clear. Darwin became uniformitarian, we may even say Lyell's disciple. It took him perhaps two years to accomplish this transition (Gruber and Gruber 1962).

Paleontology played an important role in Lyell's physical geology. From fossil evidence one could reason about the probable course of geological events. Finding beds of seashells on mountain tops suggested the former residence of the sea: either the mountains have been upraised or the sea level has subsided. Further reasoning and evidence of the same kind could decide the matter. An exciting array of issues could be dealt with in this manner.

Matters are much harder to interpret when we see Darwin using the same range of evidence to settle the biological questions of the extinction of some species and the appearance of others. Modern scholars can take the same remark to show that Darwin was coming "to face directly general difficulties in Lyell's account of extinction" (Hodge 1982, 35), or "a convinced Lyellian, which means he was committed to (1) the immutability of species; (2) local extinction and local creation as opposed to catastrophism; (3) extinction proceeding gradually by the successive deaths of individuals; (4) concept of local species distribution" (Kohn 1980b, p. 71).

This passage and its alternative interpretations are worth examining. It is a part of his Geological Notes, a few pages written in February 1835 and later removed to be filed with notes on South American geology. In the nearly 1400 pages of geological notes Darwin made during the voyage, this passage may be his first (and almost only) extended discussion of issues mentioned above. Although its interpretation has occasioned some disagreement, a few major points can be summarized.

1. Darwin rejects the idea of a single "diluvial débâcle" as the cause of extinction. He is also skeptical about a series of such events as the likely cause.
2. He is dubious about changes in climate as the cause of extinction.

3. He is interested in the compensatory relationship of regions of elevation and regions of subsidence.
4. He accepts Lyell's metaphor, likening the death of species to the death of individuals, both as natural processes.
5. He extends the metaphor to include both the "gradual birth and death of species." While the phrase, "gradual birth" occurs only once, and almost in passing, it is hard to ignore: Darwin is not only a future evolutionist, he has a past, through contact with the ideas of his grandfather, of Grant, and of Lamarck.
6. After this one *lapsus linguae* he reverts to the more Lyellian formulation, "successive births must repeople the globe." This phrase happens also to echo one of his grandfather's poems (Erasmus Darwin 1803, Canto IV).
7. He probably believes that in the order of nature which "the Author of Nature has now established" the number of species remains approximately constant.

In spite of numerous ambiguities, it seems to me that we can sum up Darwin's most general ideas about extinction at this time as lying within a certain range on a number of issues.

*Extinction*. Definitely occurs. Sudden débâcles rejected as cause. Possible mechanisms: species senescence, disadaptation due to environmental change.

*Approximate constancy in number of species*. Accepted as an explicit but unexamined premise.

*Replacement of old species by new ones*. Follows from the above. Possible mechanisms: "successive births" or "gradual births." Both are vague terms, and it must be noted that the apposition of "gradual" considerably modifies the metaphor of "birth."

In the theories then current, species death could be Sedgwick-sudden, or Lyell-gradual disadaptation, or Brocchian senescent.[3] Do we have Darwin becoming an evolutionist as early as February 1835?

On balance, I think not. All the other evidence points the other way. Kohn would probably accept the interpretation Hodge has now given the passage, as I do. Darwin was dealing with the issue of extinction in a somewhat confused way. He could not interpret his own fossil findings without more expert help, which he received later (see below). The passage does represent the beginning of his rather longstanding commitment to *some version* of the species senescence idea.

There are several versions, and Darwin probably vacillated among them. But to my mind we should not negotiate away these differences of interpretation. They reflect something important—the ambiguities in Darwin's position at *every* point in

3. Both Hodge (1982) and Kohn (1980b) concur on the Brocchian source of the species senescence idea. Lyell discussed it and disagreed with it in Vol. III of the *Principles*, which Darwin read during the voyage. Lyell learned of it from, and cited the Italian geologist, Giovanni Nattista Brocchi. I see no reason to doubt the importance of Brocchi in the story. But I would add that at least one key part of the idea, the gradual deterioration over generations, of grafted apples—an example Darwin alluded to, metaphorically, repeatedly for many years—can be found in Erasmus Darwin's poetry, spelled out in full in a prose note. What is more, the context it occurs in is the poet's celebration of the value and power of sexual love. This attitude was a Darwin family tradition. Erasmus Darwin, *The Temple of Nature or the Origin of Society: A Poem with Philosophical Notes* (1803), Canto II, p. 57.

his development. He was skillful and creative in using ambiguity productively, both to help him get on with what could be settled and to suggest openings. He was capable of living with ambiguity. Also he could sustain ambivalence, entertain several theories during the same period. Closer and closer study of Darwin's thinking should not be aimed at finding the one right pathway that correctly describes his route. He had the time to explore a number of paths. So should we.

I do not say all this in an especially conciliatory spirit, although I see nothing wrong with that. Rather, I wish to underline the value of many eyes, many minds, many station points. The way toward understanding sometimes passes through choice and other times through synthesis.

What can we now say of Darwin's commitment to Lyell? Let us review what we know.

In 1832 his unseen mentor and hero was still undoubtedly Humboldt. By sometime in 1833 he had assimilated enough Lyellian geology to reject, with increasing resolution, throughout 1833-1834, his earlier training in catastrophist ways of thought, especially concerning physical geology.

Sometime after receiving it in April 1834, Darwin began to read and absorb Volume III of Lyell's *Principles*. Not long after, Darwin began to dunk along Lyellian lines with regard to a group of related issues connecting biogeography, and paleontology with uniformitarian geology, all under the aegis of a creationist (albeit multiple creationist) point of view. These commitments are expressed mainly in Darwin's geological notes of February 1835. And it must be noted that this is not a very rich record compared with the documentation we have on other matters. Furthermore, it must be noted that even this commitment was more than a little "iffy."

By December 1835 we have Darwin (a) criticizing Lyell's theory of coral reefs and (b) questioning the immutability of species. It should be noted that even a firm belief in mutability of species would not necessitate espousal of evolution. Although there are still many points of agreement between Darwin and Lyell on biological questions, the atmosphere of discipleship, which lasted between two and three years, has dissipated. When Darwin steps off the Beagle in 1836 he is on his own.

Among Darwin scholars, there is good measure of agreement about the theoretical outcome of the voyage for Darwin's progress. To be sure, an older generation of scholars may have believed in a sudden eureka experience in or just beyond the Galapagos experience. But it is now widely recognized that there was during the voyage no grand "Aha!" about the idea of evolution, not to speak of the mechanism of natural selection. In spite of much theoretical and personal growth, Darwin had still a long way to go.

## CORAL REEFS: A THEORETICIAN UPWARD AND OUTWARD BOUND

There are two themes that appear and reappear throughout most of Darwin's life, adaptation as both state and process, and continuity through transformation. Both make an early appearance in a surprising place: Darwin's theory of the formation of coral reefs, which he worked out in December 1835 before visiting the coral islands of the Pacific toward the end of the voyage.

*Adaptation* can be thought of in two ways. On the one hand it refers to a steady state, in which the different parts of a system are so formed that they function in harmony with each other. On the other hand, it refers to a process in which adaptive change in one part of the system compensates for change in some other part. Darwin's coral reef theory argued that a series of local compensatory changes in the growth of coral organisms generates, in the long run, a continuous series of forms of coral reef. The coral organism flourishes within a certain distance of the ocean surface. As the bottom sinks, due to the action of large-scale geological processes, the live coral flourishes at a new level. Meanwhile, a corresponding increment is added to the column of dead coral. As the reef column grows upward and outward, its interaction with the rough and tumble of the sea changes in ways that account for the ultimate shape of the reef. Under different conditions, different types of reef are formed. These are not sharply distinguished but, Darwin argued, grade into each other. Thus, a series of smooth changes in outward physical forces produced a continuous series of forms: fringing reefs, barrier reefs, and coral atolls.

This theory bears a striking *formal* resemblance to the theory of evolution through natural selection. The similarities have been pointed out independently by Gruber and Gruber (1962), and by Ghiselin (1969). First, both theories contain a principle of population growth, e.g. the coral organism does not grow beyond some limiting distance from the ocean surface. In both cases the limiting principle is described by Darwin as a *struggle*—in the case of coral formations, a struggle "between the two nicely balanced powers of land and water." Second, both theories combine this limiting principle with geological ideas to explain the major facts of geographical distribution. Thus the hypothesis that a pattern of regions of subsidence of the Pacific floor (together with other geological factors) determines the places in which the coral organism grows and forms reefs. Third, both theories generate a continuous series of forms where other theories posited only certain classes. Thus for example, ", ... barrier reefs, when encircling islands, are thus converted into atolls, the instant the last pinnacle of land sinks beneath the surface of the ocean."[4]

This coral episode is important for a number of reasons. First, it shows Darwin as a confident theoretician: extrapolating not only from observations but from his own prior theoretical work; formulating the theory before ever seeing a coral reef. It shows Darwin thinking on a global scale: over wide spaces, coordinating the eleva-

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4. In most respects the above description of Darwin's coral reef theory is very close to the version I wrote in *Darwin on man*.

tion of continental land masses with the subsidence of remote ocean floors; over long periods of time, imaginatively reconstructing the formation of reefs through the interaction of geological and biological processes. It shows Darwin comfortably handling the complexities of a multi-level theory that requires: close knowledge of a small invertebrate organism; clear thinking about the consequences of its colonial mode of life in relation to its environment; working out the reef building effects of periods of elevation and subsidence; connecting all this with a still hypothetical picture of geological processes on a global scale.

Second, it shows Darwin in December of 1835 forming a theory that disagrees with one advanced by Lyell. This did not represent a sharp break with Lyellian thinking, as Lyell was quick to admit, in expressing his admiration for Darwin's idea. Nevertheless it does show that Darwin felt free to criticize his still unseen mentor.

Third, the theory expresses Darwin's interest in a more general theme, the way in which living organisms transform both their own immediate environment, and the earth in general. This "life makes land" theme was made evident in 1837 when Darwin published two papers bearing on it, the May 31st paper on the formation of coral reefs (CP 1:46-49, 1837) and the November 1st paper on the formation of vegetable mould through the action of earthworms (CP 1:49-53, 1837). The joint occurrence of the two papers, the fact that the earthworm paper seems to come out of nowhere, and the fact that both topics were taken up at later times—all this argues for the idea that the coral theory was not an isolated event, but one related to Darwin's general point of view and embodied in an enduring theme.

Since the term *adaptation* is generally used to refer to morphological and behavioral changes in the organism, the reader may question my use of it to refer to a system of compensatory changes maintaining an invariant. The key point is that Darwin's thinking, from an early date, was permeated with the idea of self-regulating systems. In the eighteenth century there had been a marked increase in the development of self-regulating machines. During the same period the concept of society as a self-regulating system became prominent in the work of Adam Smith and others. The American constitution was constructed as a system of "checks and balances." Although Darwin never used the analogy between natural selection and man-made feedback devices, Alfred Russel Wallace did. In his 1858 paper, presented for him at the Linnaean Society, he wrote of natural selection, "The action of this principle is exactly like that of the centrifugal governor of the steam engine, which checks and corrects any irregularities almost before they become evident ..." (Wallace 1858).

How like the "nicely balanced powers" in Darwin's coral reef theory!

Nevertheless, Darwin's first theory of evolution—whether we take Gruber's, Hodge's, or Kohn's version of it (or all of them as there was not necessarily only one at a time ...)—does not have a formal structure of the kind described above. An adequate account of Darwin's intellectual development should deal with that rather surprising inconsistency.

Darwin's actual visit to the coral islands was a significant event, providing him with the opportunity to make observations supporting his already constructed theory. His increase in self-confidence as a theoretician is reflected in an entry in the Diary. As the *Beagle* sailed away from Keeling Island on April 12, 1836, he wrote:

> In the morning we stood out of the Lagoon. I am glad we have visited these Islands: such formations surely rank high amongst the wonderful objects of this world. It is not a wonder which at first strikes the eye of the body, but rather after reflection, the eye of reason. (Diary, p. 400)

The sense of self Darwin experienced at this time is expressed in a letter to his sister Caroline, written April 29, 1836. He mentions his work on coral formations and remarks, "The idea of a lagoon island, thirty miles in diameter being based on a submarine crater of equal dimensions, has always appeared to me a monstrous hypothesis" (Darwin 1945, 138-139). This was Lyell's idea that he was rejecting. Later on in the letter he writes of his plans to live in London and work as a geologist, "It is a rare piece of good fortune for me, that of the many errant (in ships) Naturalists, there have been few, or rather no, Geologists. I shall enter the field unopposed."

With the theoretical equipment and empirical knowledge we have now described, it might seem as though Darwin was in a good position to move toward a theory of evolution, and that that theory would be one involving an equilibration model of the kind he already knew well, having created it himself. But there were obstacles to be removed. Chief among them were Darwin's belief, although somewhat shaken, in the immutability of species and his inability to interpret his own puzzling biogeographical and materials. These two kinds of issues were closely related, and their resolution would, it has been argued, make an evolutionist of Darwin. How were they resolved? And did their resolution suffice?

## THE SELF-CONSTRUCTION OF A TRANSFORMATIONIST

It is now widely agreed among Darwin scholars that when Darwin stepped off the *Beagle* he was not yet an evolutionist. Although our knowledge of the immediately post-voyage period is quite incomplete, Sandra Herbert's publication of the *Red Notebook* is an important landmark in scholarship for this period (RN). And Frank Sulloway (1982a, b, c, 1983) has now done a masterful job of tracking down and organizing the empirical work that moved Darwin toward transmutationism. Sulloway speaks of Darwin's "conversion" but I prefer to think of it as "self-construction"—for three reasons. First, for the whole period from about February 1835 to July 1837 Darwin seems to be moving in a direction, making a set of choices, constructing a point of view and applying it over a wide range of phenomena. Second, at any given time his belief system is assembled out of many components, each with considerable inner structure and all fitted together with some care, albeit not always perfectly coherently. Third, conversions come to an end, constructions do not—and there seems to be no end point in Darwin's activity in any of the enterprises or themes in question. This lack of finish means also that there are always loose ends and ambiguities, continually re-animating the creative process.

The reader may object to my description of movement toward a rather vague goal as purposeful. I grant that Darwin's purposes are not always clear. But remember, we are not speaking of history or of evolution; abstract criticisms of teleology are not at issue here. Human beings do have purposes, and they need to organize their work. The very concept, work, is saturated with the idea of purpose. Goal, purpose, plan, aspiration, self-concept, ideal self—these are fundamental human attributes. For years, I have wanted to become a pacifist; I may someday achieve that aim. What is wrong with thinking that Darwin, especially given his family history, may have wanted to become an evolutionist, may have been consciously aware that some intellectual moves took him in that direction and others did not?

During the voyage Darwin collected wonderful material. He later wrote that the relation between fossil and living forms in South America and the facts of geographical distribution, especially the peculiar array of species he found in the Galapagos, were critical in swaying him toward evolution (Darwin 1958, 118-119). But he was not, during the voyage, in a position to use these materials in an evolutionary theory. He was not competent enough in anatomy to make the necessary analyses of his fossils; nor was he enough of a systematist to solve the classificatory problems his far-ranging collections posed. His Galapagos collections were not complete, many specimens were initially misclassified, and the famous tortoises and finches were not adequately labeled to know which island they came from. To some extent these problems were due to Darwin's lack of expertise. But also, he lacked the evolutionary perspective that would have led him to collect and label more assiduously, island by island in the Galapagos. As he put it, "I never dreamed that islands, about fifty or sixty miles apart, and most of them in sight of each other, formed of precisely the same rocks, placed under a quite similar climate, rising to a nearly equal height, would have been differently tenanted" (Darwin 1945, 394).

To take the next step Darwin needed to fit three ideas together: first, the idea that one species could be transmuted into another; second, the idea that the repetition of such a process could accumulate over geological time to produce large differences; and third, the idea that this scenario, played out on a world scale, with organisms constantly migrating to new environments and becoming isolated from their forebears, could produce the whole system of organic nature.

To establish transmutability, the small differences among related species on the different islands of an archipelago would be ideal material. This step requires that the specimens be differentiated from each other as belonging to different species, and yet classified together as belonging to the same genus. Moreover, if the fundamental biogeographical connection is to be made, the specimens collected must be correctly labeled as to their location. For the birds of the Galapagos Archipelago, the collaboration of the ornithologist John Gould was indispensable, and the work was done between January 4th and early March, 1837. The ornithological findings broke the "species barrier" (Sulloway's phrase): there was no longer an intrinsic limit keeping variation within the boundaries (on which Lyell had insisted) of the species. Other zoologists contributed to the new picture, but Gould's work was the most important.

But establishing the transmutability of species would not lead to a full-scale evolutionary conclusion unless coupled with the more general changes that could only be observed over wider reaches of space and time. Regarding geological time, the paleontological work of Richard Owen was the key collaborative effort. This work began in December 1837. Almost immediately, Owen was able to pronounce that Darwin's fossils included a rodent *(Toxodon)* the size of a rhinoceros and an anteater *(Scelidotherium)* the size of a horse. These and other findings were communicated to Lyell. In his presidential address to the London Geological Society on 17 February 1837, Lyell summarized Owen's findings. He showed how these results dramatically confirmed the law of the succession of types: on large continents, existing species and extinct ones are closely related anatomically. This law really has two parts: first, new species closely resemble the ones they are replacing; and second, the difference between species sufficiently separated in time can become very great.

It should be noted that this law was by no means a new discovery.[5] Why did its confirmation now help move Darwin toward an evolutionist commitment? Perhaps—the dramatic confirmation, using his own fossil specimens, and the attendant recognition he received, provoked him to think more about it. This highlighting of a known idea took place just as other key results of the voyage were coming into focus, and it was, after all, the integration of such widely different classes of data into a new synthesis that became Darwin's role.

The third class of data growing out of the zoologists' processing of the *Beagle* specimens has to do with the issue of representative species. Darwin revealed some awareness of this idea in his celebrated ornithological notebook in a passage (now dated by Sulloway as written June or July 1836) mainly on the birds of the Galapagos, but also mentioning the foxes of the Falkland Islands. Darwin was struck by the point that organisms "slightly differing in structure and filling the same place in Nature" could be found in different places. But that famous note remains ambiguous, in good part because Darwin injected the phrase, "I must suspect they are only varieties." Only if this suspicion was removed would "such facts ... undermine the stability of species." The suspicion was not alleviated until early 1837, when the zoological results of the voyage poured in. Extended over a wider scale, Darwin's intuition (as against his prudent "suspicion") was richly confirmed. At a taxonomic level higher than species, there is a broad pattern of resemblances between the forms found in neighboring regions. The greater their isolation from each other—in time, reinforced by space and other barriers—the greater the differences. But islands typically have a general relation of similarity to nearby continents in their flora and fauna.

5. For a brief account of this history, see Eiseley (1958), pp. 161-166.

In the *Red Notebook*, this idea is conveyed in an odd phrase: "... new creation affected by Halo of neighboring continent ..." (RN 127, written mid-March, 1837). In one possible reading, Darwin is suggesting that a geographic region somehow imposes a character on its organic productions. In his discussion of this passage, where Darwin wrote "peculiar plants created," Sulloway has added "[by colonization and gradual transmutation]." This is a plausible interpretation of Darwin's meaning, but certainly not the only possibility.

Thus, to assimilate his zoological work of the voyage to his emerging scheme, Darwin had to clarify the relations among three quite different classes of results. No one of them alone required an evolutionary explanation. Even all of them together could be assimilated to other theoretical schemas.

Sulloway has argued convincingly that the new information that Darwin gained from the expert processing of the *Beagle* specimens is not sufficient to account for his turn toward evolutionism; others sharing the same knowledge, indeed responsible for producing it, did not move in the same direction as Darwin. Sulloway attributes the difference to Darwin's "genius." I will not discuss here whether genius is an adequate explanatory concept (see Gruber 1982c). However that question is decided, we must try, as well as possible, to understand what other moves Darwin was making that would lead him to the turn he took.

The *Red Notebook* may offer some help. Most scholarly attention has been centered on the frankly evolutionary or proto-evolutionary passages in the second half of it, written probably from the end of May 1836 to the close of the voyage. But here I want to draw attention to the first half, which deals mainly with more strictly geological issues.

## GOING THE LIMIT

What strikes me in the *Red Notebook* is an aspect of his style of thought. He is interested in pushing ideas to their limits, in making global generalizations. He writes of the need to focus on one region (for him, America), then to draw parallels with what is known about Europe, and finally to draw conclusions "applicable to the world" (RN 18). Since he knows how marine organisms capture lime, and he believes that this has gone on for a very long time, he asks, "How does it come that all Lime is not accumulated in the Tropical oceans detained by organic powers. We know the waters of the oceans are all mingled" (RN 29-30).

He is interested in the relation between very small events and their accumulation to great effects, sometimes not such obvious ones. Thus he tries to explain how gradual processes can lead to coastal steps (RN 39-41). He returns to this point a little later: "Mr Lyell ... considers that successive terraces mark as many distinct elevations; hence it would appear he has not fully considered the subject" (RN 60). The more general idea of a qualitative leap emerges in another form in a reference to an experiment by Humphrey Davy showing that a small electric charge on a ship's copper bottom (produced by a bi-metallic contact) prevents fouling: "From Sir H. Davy experiment on the copper bottom, we see a trifling circumstance determines whether an animal will adhere to a certain part" (RN 95).

The question of scale occurs over and over in different forms. In writing of the flow of seemingly solid earth, he writes, "Mountains, which in size are grains of sand, in this view sink into their proper insignificance; as fractures, consequent on grand rise, & angular displacement, consequent of injection of fluid rock—Try on globe, with slip paper a gradually curved enlargement" (RN 48). His mind moves eagerly from one scale to another: "Volcanos must be considered as chemical retorts" (RN 78). Within a few pages he remarks on "immense time," "immense areas," and "stupendous mass" (RN 107-109).

The idea of systems of compensating variables comes up repeatedly. He is fascinated by proposals that the system of volcanic action is a global system of subterranean forces. A line of volcanos in the Cordilleras could have "originated ... from a fissure in a deep & therefore weak part of the ocean's bottom" (RN 10). The system of variables captured in the phrase "deep and therefore weak" deserves reflection.

Thus, while still on the voyage he was perfecting a style of thought in which (a) ideas are pushed to both their limits, such as the very great and the very small; (b) relationships are worked out between these extremes, and are often not obvious; and (c) since the limits in question include time as well as space, matter, and energy, the question of ultimate origins is never very far away.

We do not know just when the note on the inside cover was written, but it was appropriate for Darwin to place it at the front of the *Red Notebook*.

> The living atoms having definite existence, those that have undergone the greatest number of changes towards perfection (namely mammalia) must have a shorter duration, than the more constant: This view supposes the simplest infusoria same since commencement of the world. (RN, inside, Front cover)

## THE FIRST NOTEBOOK ON TRANSMUTATION

We now turn to the beginning of the B Notebook, a momentous step for Darwin. Darwin announces that something is happening. He begins a new notebook. He names it *Zoonomia*, the title of his grandfather's evolutionist essay (Darwin 1800). Most important is the change of style. The first thirty pages or so are no longer a miscellany of jottings, but a connected series of reflections. I will take the passage a few pages at a time. On the whole, within the passage, late ideas are added to or combined with earlier ones; revisions and rejections come later.

1. Adaptive change is necessary. This is nowhere stated but assumed throughout.
2. The function of the life-cycle is to make adaptive change possible. "Generation" is used to refer to the cycle of reproduction, maturation, and death. "There may be unknown difficulty with full grown individual with fixed organisation thus being modified,—therefore generation to adapt and alter the race to chang-

ing world. On other hand, generation destroys the effect of accidental injuries, which if animals lived for ever would be endless ... Therefore final cause of life" (B 4-5).

3. If the young must be born, this is taken to imply the necessity of death. In other words, the population remains approximately constant.
4. Variation is necessary for adaptive change. Two mechanisms are discussed, sexual reproduction and direct response to environmental circumstances. The latter is not the Lamarckian idea of inheritance of acquired characteristics. Rather, by some unspecified mechanism, change is induced during reproduction. For example, "seeds of plants sown in rich soil, many kinds are produced ..." (B 3).
5. Variation must be disseminated to a whole population. The theory is not about individual adaptation but about populations and species. This is accomplished by sexual reproduction: "With this tendency to vary by generation, why are species all constant over whole, country [?] Beautiful law of intermarriages partaking of characters of both parents and then infinite in number" (B 5).
6. There is an explicit denial of the efficacy of asexual reproduction as an agent in this process of adaptive change: the offspring are uniform. This leaves a question unsolved: Did Darwin think that asexual organisms do not evolve? Did he think that all organisms are at least occasionally sexual? Or was the denial not so absolute, perhaps a rhetorical device to accentuate the value of sexual reproduction? These questions are confused with that of the significance of the opening lines, on pages B 1 and B 2. Kohn (1980, 84) takes them to be a clear and succinct summary of a passage in Erasmus Darwin's *Zoonomia*. I fail to see such a close resemblance, and see the passage as a still rather confused paraphrase extension of a passage in the *Red Notebook* (RN 132), with a reference to *Zoonomia.* But we do not need to settle these questions in order to agree on the others. This opening passage strongly suggests Darwin's aspiration for a theory that would go from monad to homo sapiens: from "the original molecule" to "civilized man." Both phrases occur here.

B 6-13. These pages deal with the wider consequences of the initial moves. Darwin begins to discuss the set of resemblances and differences that form a taxonomic system broad and flexible enough to encompass island-to-island differences in an archipelago, representative species in different regions of a continent, and the peculiar pattern of resemblances (which he had earlier called a "halo") between a continent and a nearby island in their flora and fauna. Both geographical and sexual isolating mechanisms are mentioned.

B 14-17. The relation between the extinct and extant animals of a region is cited. Historical geology is brought to bear. "Countries longest separated—greatest differences" (B 15).

B 18-23. The issues of the limits of the system, and the direction of evolution come into focus: "Each species changes. Does it progress [?] Man gains ideas. The simplest cannot help becoming more complicated; and if we look to first origin there must be progress" (B 18). So far as direction goes, Darwin is cautious but clear: there must be progress.

So far as the first limit of the system, its origin, is concerned, Darwin makes two points about monads, or simplest living forms. First, if monads are constantly formed, there would be lawful similarities among them, due to prevailing worldwide conditions. Second, if monads have a specifiable, finite existence, then their derivatives share this duration in lawful ways.

7. Isolating mechanisms, geographical and sexual, are necessary to stabilize species change.
8. The metaphor likening the life-cycle of a species to that of an individual, which appeared much earlier in his thinking, is reiterated. "There is nothing stranger in death of species, than individuals" (B 22).
9. Not only population, but the number of species remains approximately constant.
10. The taxonomic system is a branching one. "Organized beings represent a tree, irregularly branched; some branches far more branched,—hence general. As many terminal buds dying as new ones generated" (B 21) Notice that these "buds" must vary, since the intent of the metaphor is to describe the evolution of new species, so they are not the literal buds of a real tree in Erasmus Darwin's *Botanic Garden*.

One of the vexed points in pages 1-23 is the status of extinction. Darwin clearly implies a system of nature in which extinction is both a lawful phenomenon and a formal requirement if new species arise while the species number remains constant. But what is the mechanism of extinction? The phrase, "death of species" states the problem but not the mechanism. There is only a hint of the idea of cumulative disadaptation. The idea of species senescence is not expressed here. Only the idea that I have called "monad life span" — with the rider that the monad includes the things it becomes — is clearly stated. It seems to me that one plausible reading of the passage in question is this: Mammalia have evolved the most from their monadic origins; that is, they have undergone the most change. Species longevity is inversely proportional to amount of change undergone; "Hence shortness of life of mammalia" (B 22). Built into this reading is the idea that the monad life span is being shared among its derivatives. So in spite of the copious criticisms Hodge and Kohn have heaped on me, I stand unrepentant on this point. For a brief period Darwin entertained the monad life span idea as a mechanism of extinction. Recognizing this idea is important in order to see the significant change Darwin soon underwent. Whether Darwin at this time relied on monad life span, species senescence, or cumulative disadaptation due to environmental change—or some combination of them—it is clear that he was unsatisfied with his position. And it is reasonably clear that he moved soon to what I have called the idea of "becoming" (Gruber 1981b): unless species change they "die" (B 61-63).

Most important of all, the branching model emerged together with these considerations, and it deserves attention. The series of tree (and coral) diagrams in the B Notebook evolved over the years into the only diagram in the *Origin*, and the one that was used to explicate the important idea of divergence. At this early time, I believe Darwin saw branching evolution as a good way to describe the empirical facts of taxonomy, biogeography, and paleontology. Moreover, he had some trace of the idea of the exponential growth function implicit in any branching model, and this was soon to become quite explicit. Except for the phrase "irregularly branched" (Darwin's italics) and a certain feel of the whole thirty pages, there is little to suggest that Darwin had a clear view of the probabilistic view of nature that would eventually justify the branching model.

## FROM MONAD TO MAN

If the theoretical issues at stake for Darwin and his contemporaries could have been contained within the shift from within-species *variability* to between-species *mutability*, their lives would have been much simpler. But it was not hard for them to see that once the "species barrier" was broken, an explosive theoretical change might set in. In the pre-Darwinian debate, the issues of evolution and of the natural origin of life were considered as twin (Farley and Geison 1974). In *Zoonomia*, for example, Erasmus Darwin dealt with them together.[6] In the 1850s, in his Species Notebook, Lyell remarked repeatedly that transformationism could not be contained at either end of the scale. He took some solace in Lamarck's view (as compared with Darwin's) that monads were still being constantly produced by spontaneous generation; this squared with his uniformitarian conscience (Lyell 1970, 124-125). Thinking about both limits together was not restricted to the Darwins and Lyell. In 1860, Leonard Jenyns wrote to Darwin, perceptively noting that in the *Origin* Darwin had gone to both extremes. In the conclusion of the *Origin* Darwin wrote plainly and vigorously: "probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed" (Darwin 1859, 484). Only a few pages later he wrote, far more prudently, "Light will be thrown on the origin of man and his history" (p. 488). Jenyns pointed this out and centered his objections on exactly this issue, the scope of Darwin's theoretical aims.[7]

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6. Erasmus Darwin, *Zoonomia*, Section XXXIX, "Of Generation." See also the *Temple of Nature*, "Additional Note I," which is an essay on spontaneous generation of simple organisms. The sections of this poem have the following titles: Canto I, "Production of Life"; Canto II, "Reproduction of Life"; Canto III. "Progress of the Mind"; Canto IV, "of Good and Evil."

7. Jenyns' letter is reprinted in *Lyell's Scientific Journals* (1970, 349-351).

But the shape of these conclusions in the *Origin* is quite different from the shape of Darwin's career as a whole. Faced with the prospect of both "going the whole Monad" and "going the whole Ourang," he made a lop-sided decision. He decisively dropped the issue of the origin of life. It is simply not present in his later work. The trenchant sentence in the *Origin* quoted above represents an abstract conviction, not a program of work. But at the other end of the scale, circumspect as he was in the *Origin*, he labored mightily and took a clear stand, early in the M and N Notebooks, and much later in *Descent* and *Expression*. When was this asymmetrical decision made? In the B Notebook, both ends of the scale are moderately well represented, although neither was his main preoccupation. In the Spring of 1838 he wrote, "The intimate relation of Life with laws of chemical combination, & the universality of latter render spontaneous generation not improbable" (C 102e). Meanwhile, the C Notebook was full of remarks about *Homo sapiens* and by July 1838 he began the M Notebook, on man, mind, and materialism. In several places in the transmutation notebooks Darwin reiterated his mysterious idea, "If all men were dead, then monkeys make men. - Men make angels" (B 169). But nowhere do "monads make monkeys." Here again we see Darwin's use of deferral and ambiguity. He put one question firmly aside, and buried the other in his notebooks.

And yet, when the time came, anticipating his readers' question "It may be asked how far I extend the doctrine of the modification of species" (Darwin 1859, 483), opening the section quoted above, he answered in his odd mixture of forthrightness and circumspection.

We have seen how Darwin experimented with the idea that the longevity of a species is inversely proportional to its position in the scale of nature: the more evolved species, i.e., mammalia, have the shortest species life span. This idea soon gave way to a quite different formulation.

> ?Law: existence definite without change, superinduced or new species. Therefore animals would perish if there was nothing in country to superinduce a change? (B 61)

In this new formulation, amount of change is not mentioned as a consideration. On the one hand, the particular change must be in some sense adaptive. On the other hand, change itself is necessary. Fortunate is the species that inhabits a region where something will "superinduce a change." Although stated here between question marks, the idea is reiterated several times and soon becomes quite definite:

> If *species* generate other *species*, their race is not utterly cut off: - like golden pippins, if produced by seed, go on, - otherwise all die. - the fossil horse generated in S. Africa zebra - and continued, - perished in America. (B 72-73)

In the sense that one species is transformed into another, the first is the parent of the second—and in the making of it enjoys a "second life," the phrase Darwin used in his notes on marriage and having children (Darwin 1958, Keegan and Gruber 1983). This does away with any clear meaning that might be assigned to the species life span idea and its variant, monad life span.

Dropping the ideas of species life span, monad life span, and original monads from his thinking was an important step, tantamount to a decision to deal with the system of nature as an ongoing system, and to avoid questions of ultimate origins.

But there were numerous vacillations and backslidings, and it was not until May 1839 that he could write unambiguously, "My theory leaves quite untouched the question of spontaneous generation" (E 160).

## TOWARD NATURAL SELECTION

Here the story diverges in a number of ways. Intricate as each path may be, I can only summarize briefly.

First, there is the main line—from the explorations in the B Notebook in July 1837 to the moment some fifteen months later when he read Malthus's *Essay on Population* (1826) and formulated the principle of evolution through natural selection. Insisting too much on the singular and climactic nature of this moment misses important points. There was the work he had to do to arrive at September 28, 1838. Then, there was the work of the moment. As Kohn (1980b) has nicely shown, the "moment" of insight had a complex inner structure. Darwin wrote and then, probably immediately, rewrote his ideas. I believe that in the initial version there is a predominant tendency to take species, and in the rewrite to take the individual as the unit of analysis.

The work of the moment also included the task of significantly transforming Malthus's ideas (Keegan and Gruber 1983). The latter anthropocentrically dichotomized the world into a human population tending to increasing geometrically and a food supply increasing arithmetically. For Darwin, the food was also organisms, all with a potential for exponential population growth, unless checked. So generalizing and de-centering went hand in hand. Moreover, Malthus wrote within a context of social theory in which the complex interrelationships among human sexuality, population growth, and social class differences were matters of intense controversy. Darwin abstracted one key idea out of this context and turned it upside down—from the scourge of humanity to the motor of evolution. The first mention of Malthus in the M and N Notebooks occurs in an entry made between 4 and 7 October 1838, only a few days after the great moment. It has nothing much to do with the population principle, but deals with Malthus's other preoccupation, sexual continence. The first and probably only suggestion of the principle of natural selection in the M and N Notebooks occurs on about March 16, 1839:

> N.B. According to my view marrying late, will make average of life longer. -
> for short-lived constitutions will then be cut off. (N 67)

Second, there is the issue that went underground for so long, the question of divergence. The early B Notebook pages strongly suggest the fact of divergence. But why? As Janet Browne (1980) has shown, when Darwin came back to this question in the 1850s, the language he used resembled that of the B Notebook. What he did not settle in 1837-1838 was the reason for divergence: what makes it necessary? It is widely agreed that it was not until the 1850s that he succeeded in answering that question to his own satisfaction (Browne 1980; Schweber 1980; Ospovat 1981; Kohn 1980a).

Third, there is the seeming tangent—the initial exploration of the evolution of mind, recorded in the M and N Notebooks. This was not only an effort to extend the theory of evolution to one of its limits, but also to use the limiting case—a "frontier instance," Darwin called it (N 49)—to solve problems within the theory of evolution. This is a subject still largely unexplored.

Fourth, there is the disputed issue of artificial selection. Several authors have argued that Darwin came to natural selection via artificial selection. It is true that in the C Notebook and the D Notebook before Malthus there is much about plant and animal breeding. But it now seems clear that Darwin was investigating the work of breeders in order to find clues to the mechanism of variation: in some way, breeding under artificial conditions was thought to disturb the natural process of sexual reproduction. Nevertheless, this process of steeping himself in the subject was fruitful; when he did arrive at the idea of natural selection, he could then turn around 180° and use artificial selection as a small scale demonstration of the principle. Even this seemingly small step took some months.

While the model of artificial selection may have been a stepping stone on some of the possible paths to natural selection, it was not a necessary way station. As late as 1858, Alfred Russel Wallace arrived at natural selection while explicitly denying the relevance of results of artificial breeding.

## CONCLUSION

I think it is at least tacitly agreed that Darwin's development was a true epigenesis: a series of structures with each phase growing out of the previous, always in interaction with new circumstances provided by a changing scientific and social environment. No one has suggested that when Darwin set out on the voyage he knew exactly where he was going, or that when he began the First Transmutation Notebook the theory of evolution through natural selection was a foregone conclusion. At the same time, Darwin's intellectual activity was far from random exploration. Starting at some early point, he seems to have been moving in a direction. In part this direction was given by certain family traditions, in part by broader historical currents to which he was exposed, and in part by his opportune encounter with Lyell's *Principles*. The voyage itself seems to have evoked in him a strong tendency to be that kind of natural historian who goes beyond local description and explanation to generalize on a world-wide scale. Perhaps we should say that the voyage reinforced a tendency already evident in his pre-Beagle admiration for Humboldt's *Personal Narrative*. The combination, tradition x education x circumnavigation, made a global thinker of the young naturalist.

As Darwin's sense of purpose emerged, it rapidly became more and more complex. We have summed up and surveyed this pattern in the "network of enterprise"—a diagrammatic way of showing the simultaneous development of a number of strands of scientific work. One of the themes of this essay has been the need to make sense out of this diversity.

Throughout this early period, we see the emergence and spread of a number of thought-forms. Among the most prominent is the summing of small effects over many iterations to produce large, often surprising results: "the multiplication of little means" that Darwin found such a "laborious and painful effort of the mind" (C 75). This idea involved, for Darwin, the movement from one time-scale to another, from the scale of localized events to the scale of their long-range consequences. So the scale of time and space intellectually available profoundly affects the significance of such summative processes. For Darwin, this scale rapidly became geological in time and global in space.

A second very general thought-form we see emerging in Darwin's work is the equilibration model. Each natural phenomenon hovers around some value governed by a host of factors. Departures from this value provoke an equilibrating process. This is not quite the same as a static "balance of natures" since from an early point Darwin was thinking of a changing world, so this re-equilibration was a moving process, as shown dramatically in his theory of coral reef formation.

A third characteristic of Darwin's thought was to think in terms of the whole range of phenomena within whatever domain was in question. Just as geological processes were happily generalized on a world scale, when he saw his first Tierra del Fuegian he immediately thought of the whole range from wild animal to civilized man. When he encountered, in his reading of Lyell, the idea of the "death" of species, he wondered also about their "birth." If one was gradual, why not the other? Moreover, he often thought about the connection between the very small and the very great.

This characterization helps to understand Darwin's evident tendency, at the beginning of his thinking about evolution, to raise questions about the scope of the theory: What is the function of birth and death of individuals? Of species? Can one theory go all the way from simplest living being to most complex, from monad to man?

There has been a valuable trend, in writing about Darwin, to "normalize" his life—to show how he became a true professional, how his work depended on that of other true professionals. This is important if we are to demystify, as far as possible, his achievements. This procedure is likely to accentuate that part of his thinking which was in the solid middle-of-the-range of scientific work.

At the same time, this normalized picture of Darwin de-emphasizes that part of his thinking in which he was testing the limits, exploring the possible scope of his theory. But the scope he achieved was a fundamental part of his contribution. Darwin was a revolutionary thinker. We need to understand what forms of thought he used that permitted him to consider so deeply and so unflinchingly the whole range of possibilities.

# Diverse Relations between Psychology and Evolutionary Thought

*When we first begin to believe anything, what we believe is not a single proposition. It is a whole system of propositions. (Light dawns gradually over the whole.)*
Ludwig Wittgenstein

"Multiply, vary, let the strongest live and the weakest die"—This quotation from the *Origin of Species* was the astonishing title of a presidential address to the *American Psychological Association (APA)* in 1943 (Stone 1943). We may well ask, how much has the theory of evolution affected the history of psychology? If the theory could be adequately summarized in the stark selectionist doctrine just quoted, or in some other simple formula, we might cite a few such historical facts, write q.e.d., and pass on the next question. But theories and their histories, like life, are never so simple.

Consider, for example, the stark contrast between the title of Calvin Stone's 1943 address and the 1909 *APA* presidential address of Charles H. Judd, entitled "Evolution and Consciousness," in which he wrote, "Psychology ... deals in a broad way with the evolutionary processes by which consciousness arose and through which the trend of life has been changed from organic adaptation to intelligent conquest" (Judd 1910).

As I have tried to show in *Darwin on Man* (1981e), the theory of evolution through natural selection is an exceedingly complex system of ideas; its complexity and density are only matched by those of the creative thought process entailed in Charles Darwin's struggle to construct the theory.

The present essay deals not with the theory as a whole but only with the place of our species, *Homo sapiens*, in Darwin's argument. I try also to show the diverse social and intellectual forces with which he was contending.

The theory of evolution has indeed deeply affected almost every psychological theory since the beginnings of scientific psychology sometimes in the nineteenth century. But without further examination this is not a very illuminating comment, since there is not one theory but a domain of theories of evolution. In most theories, natural selection operating on chance variations is the major factor. But chance can be construed in very different ways. At one extreme, there is the notion of mutations as relatively rare events due to forces extrinsic to and independent of the organism (such as radiation); at another extreme, there is the view of chance as the systematic exploration, albeit through blind trial and error, of all of the structural possibilities open to a given genic organization. It would seem that a view of organic nature as undergoing perpetual change is the central idea of evolutionary theory. But this is not the idea that psychoanalysts and sociobiologists drew from it. On the contrary, in a style that owes

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more to Newton than to Darwin, they have stressed the existence of constants in nature, unvarying instinctual behavior. This is certainly one way to approach the issue of continuity between *Homo sapiens* and other animals. But it is not the only way. There have been other thinkers who have tried to draw from evolutionary theory an understanding of the way in which our species' unusual cognitive capacities and emotional toughness and flexibility, leading to an enormous variety of cultures and societies, grew out of the more limited psychological capacities of our animal forebears.

Finally, there are different theoretical stances regarding the causal relations between behavior and evolution. On the one hand, it is possible to stress the idea that structural changes (through chance mutations) make possible new behavioral adaptations. On the other hand, Piaget was not alone in considering behavior to be the "motor" of evolution. This latter approach forms a congenial partnership with another idea: Upon the emergence of our species a genuinely new force appeared in nature, cultural evolution.

Now, in a few pages, I want to examine the very partial and disjointed assimilation of evolutionary theory in psychological thought. I will draw heavily upon *APA* presidential addresses and upon a few seminal writers (e.g., Freud, Piaget), because these sources give a sense of the main alternative theoretical pathways actually available to most psychologists and to their students. But the reader will notice that these pages are not a history of the subject they deal with. Ideas are not presented in chronological order but in a way intended to provide a sketch of some of the major theoretical landmarks in what remains a very contemporary scene.

## APPROACHES STRESSING THE ROLE OF EVOLUTION IN SHAPING BEHAVIOR

Let us begin with Sigmund Freud and psychoanalytic theory. Freud (1953) hailed Darwin, likened him to Copernicus for his part in dethroning our species from the grandiose view that we are the center of the universe and the highest object of God's creation:

> In the course of centuries the naive self-love of men has had to submit to two major blows at the hands of science. The first was when they learnt that our earth was not the center of the universe but only a tiny fragment of a cosmic system of scarcely imaginable vastness. This is associated in our minds with the name of Copernicus, though something similar had already been asserted by Alexandrian science. The second blow fell when biological research destroyed man's supposedly privileged place in creation and proved his descent from the animal kingdom and his ineradicable animal nature. This revaluation has been accomplished in our own days by Darwin, Wallace, and their predecessors, though not without the most violent contemporary opposition (Freud 1953, 296).

But Freud and other sociobiologists have borrowed one-sidedly from Darwin. They emphasize the animality of *Homo sapiens* at the expense of our humanity. Insisting on the essential identity of our mentality and behavior with the instinctual behavior of infra-human species, they advance the idea that *Homo sapiens* is "nothing but" an animal. There is another way of thinking about the subject, more consonant with a fully evolutionary theory. Our long evolutionary prehistory can be viewed as providing the springboard for a radically new event in nature, the appearance of a species capable of elaborate language systems, of cumulative cultural history, and of reflective thought.

This view does not eliminate the task of understanding the relation between emotion and thought, but it does profoundly alter it. At every stage in the growth of an evolving system, the constantly changing relation between form and function opens the way for genuine novelty. In a double sense, the system of nature changes itself. On the one hand, it cannot go backward: Evolution consumes its own past, each moment destroys the conditions that made it possible. Thus, it is impossible for our species to revert to the instinctual forms of our precursors. On the other hand, every step of evolution makes a new future possible. Thus, it is not necessary for us to live within the confines of our past. Although it is true that Darwin did much to show the "animal" nature of our species, he was equally at pains to explore the intellectual accomplishments of other organisms. As evolutionary latecomers we express both traces of the past and promises of the future. It was this well-roundedness of Darwin's thinking about the continuity question that permitted him to close his book *The Descent of Man* with an evocation of man and his "godlike intellect." Three important currents in psychological thought—behaviorism, psychoanalysis, and Social Darwinism (later revised under the name of sociobiology)—all drew upon Darwin's work in a similar way. All three were movements that placed overwhelming emphasis on the animal origins of humanity, as against the "far more perfect creature" Darwin thought he saw in the making (Darwin 1958).

Today's evolutionary psychology can be read in a somewhat different spirit: Natural selection as model or metaphor for diverse psychological processes. Darwin's argument for the evolutionary continuity of human and animal mentality was steadily transformed into the antimentalism of behavioristic psychology. Skinner (1938) acknowledged that this required three steps: Darwin ascribed mental powers to animals; Lloyd Morgan continued the development of comparative psychology by advocating the elimination of mind as a legitimate concept in the study of animal behavior; and J. B. Watson endeavored to "re-establish Darwin's desired continuity without hypothesizing mind anywhere" (p. 41). I believe that Darwin would have been happier with psychologists who, like the Gestaltists, preserved the idea of continuity by developing experimental methods for studying insightful problem-solving behavior in infra-human species (see, e.g., Köhler 1976).

By and large, the behaviorists exploited the Darwinian selectionist formula in a strict and narrow way. In his *APA* presidential address, Clark Hull (1937) began with an obeisance to Darwin. Then he presented his learning theory in the form of eighteen definitions, six postulates, and thirteen theorems. The fourth theorem states the principle of variation: "Organisms in simple trial-and-error situations may manifest spontaneous variability of reaction, the objective situation remaining constant ..." (p. 325). The seventh and eighth definitions state the principles of selection. A correct or "right" reaction is a behavior sequence which results in experimental extinction. The choice of the term extinction clearly shows the evolutionary roots of behaviorist learning theory.

Nor is this kind of learning theory the only place in psychology where the narrow selectionist formula has been applied. For example, this is the theoretical schema underlying much of the experimental literature on creativity. Unable or unwilling to study the creative process as a whole, some psychologists have redefined their problem as the study of originality, or the production of unusual responses. The key experimental idea is to separate the processes of variation and selection from each other and to focus attention on the first phase, variation, and moreover, variation construed as a random process.

There have, however, been psychological theorists motivated by evolutionary thought who did not restrict themselves to this narrow formula. In spite of the narrow selectionist focus of its title, Calvin Stone's address actually did grasp some of the open-endedness of behavioral evolution. More recently, M. Brewster Smith (1978), in another presidential address to *APA*, presented the kind of open, continuously evolving perspective of which I now write. Drawing on Jean Piaget, George Herbert Mead, and Karl Marx, he examined the way in which the growth of mind changes the material setting in which it evolves, and vice versa. He elaborated the theme that the growth of language and cognition permits the appearance and development of reflective selfhood, and vice versa. Finally, he conceived of all these as mutually synergetic processes at work in a continuous pattern of spiraling growth.

For Donald Campbell, the use of evolutionary theory as a tool for understanding all knowledge process—"evolutionary epistemology," as he termed it—was an abiding passion and a productive enterprise. His *APA* presidential address in 1975 bore the complex title *On the Conflicts between Biological and Social Evolution and Between Psychology and Moral Tradition*. He wrote

> The evolutionary theory I employ is a hard-line neo-Darwinian one and ... is the only and all-purpose explanation for the achievement of fit between systems and for the achievement and maintenance of counter entropic form and order. (Campbell 1975, 1105)

In spite of his epithet "hard-line," the careful reader will notice the use of the word systems in the plural. Campbell was not merely speaking of the adaptation of organisms to the systems of nature. He had two systems in mind, the system of biological evolution and the system of cultural evolution. Their interplay creates complexities that cannot be dealt with through the simplistic use of a purely biological model of evolution. Campbell argued that any evolving system entails the operation of four kinds of mechanisms: variation, selection, retention, and duplication (or reproduction) of that which has been retained. But the exact nature of these mechanisms may be entirely different in a purely biological infra-human system and in a human cultural system.

Although Campbell insisted that variations are "blind," it is important to notice that this blindness is an epistemological constraint meaning only ignorance of the ultimate utility and impact of any innovation or variation. At the human cultural level, Campbell's epistemological blindness is not so different from the philosophers' "learned ignorance." It certainly does not mean that humans are unintelligent or mindless. We grope, but not mindlessly. This is a plea for epistemic humility (Campbell's phrase), not a denial of mind. Campbell used the same apparatus of evolutionary thought (variation, selection, retention, duplication) at both levels of his two-system model. The resultant situation is not a smoothly functioning coherent world, but one that is fraught with inherent contradictions:

> 1. Human urban social complexity has been made possible by social evolution rather than biological evolution. 2. This social evolution has had to counter individual selfish tendencies which biological evolution has continued to select as a result of the genetic competition among the cooperators. (Campbell 1975, p. 1105)

Thus, although Campbell's epistemological and social program is broad and subtle, the structure of his argument and the contents of his psychological theory are not so different from Freud's: Biologically evolved genetically determined instincts or tendencies are controlled by socially evolved cultural mechanisms; instincts that are supposed to have evolved over millions of years remain essentially unchanged.

## APPROACHES STRESSING THE ROLE OF BEHAVIOR IN DIRECTING EVOLUTION

The anthropologist Washburn (1978) is among many who criticize this sort of extrapolation form animals to humans. He wrote:

> Students of animal behavior feel free to use the behaviors of non-human species when making points about human behavior. For example, in a recent book, the chapter on human behavior cites the behavior of many non-primates to make important points. The possibility of atavistic behaviors in human beings is illustrated by a picture of a musk-ox in a defensive position. To show how peculiar this habit of proof really is, consider what the reaction would be if I sent to a zoological journal a paper on the musk-ox with defensive positions illustrated by the British Squares at the Battle of Waterloo (Washburn 1978, 414).

There is a considerable number of anthropologists, evolutionists, and paleontologists who stress the explosive rapidity of recent evolution "toward" *Homo sapiens sapiens*, our species. A number of factors seem to have combined in multiplicative fashion to produce the qualitative leap to humanity. In general, this group of investigators tends to stress the role of behavioral changes in driving organic evolution, especially at the hominid level. For example, upright walking permits collecting food (by freeing the forelimbs, or hands); collecting food permits bringing it to a place where it can be shared with others; such sharing permits the development of a stable, homelike abode; this new (for primates) situation facilitates the transformation of a primarily emotional system of communication into true language.

These evolutionary events do not happen in a linear sequence. Rather, a little progress along one front opens the way to change on some other front. Not only genes but protocultures are transmitted from one generation to another. Individuals and groups that invent and transmit valuable behavioral adaptation tend to survive; this allows time for neurological and other structural changes to evolve (through mutation and selection) that will make the recurrence and elaboration of these behaviors more probable. The traits that evolve and endure need not be highly specified behavior patterns. As Washburn (1978) wrote about one much discussed trait, "There is, obviously, no need to postulate genes for altruism. It would be much more adaptive to have genes for intelligence, enabling one to be altruistic or selfish according to the needs of the moment" (p. 416).

The view that I have just sketched out for the evolution of behavior is quite similar to the geneticist Waddington's (1957) idea of genetic assimilation. At the ontogenetic level, organisms increase their chances of survival if they make appropriate phenotypic responses to environmental demands. The preferential survival of those individuals that have such responses within their range of reactions leads to the incorporation of their genie partners in the gene pool of the population. It should be noted that Waddington still relied basically on natural selection and chance mutation to consolidate gains first achieved at the phenotypic, ontogenetic level.

Piaget went even further. In his book *Le Comportement Moteur de l'Evolution* (1976b)—the title of which is inexplicably translated as *Behavior and Evolution* (1978) in the published English version, instead of *Behavior, the Motor of Evolution*—he argued that all evolution, not only human, is primarily induced by behavioral changes that lead to genetic changes. He insisted that his position is not Lamarckian, and he advances a general hypothesis to explain how appropriate genetic variations could occur, tuned to environment demands, without relying on occasional chance mutations (Piaget 1978). Thus, he is arguing not only for the primacy of behavior in evolution but against the role of blind variation.

However, to see in just what measure Piaget rejected the idea of blind variation, we must examine the concept a little more closely. Piaget views the process of variation as a systematic exploration of a set of possibilities. This combinatorial attack or "organic logic" gives the initiative to the organism rather than submitting it to a process of waiting for the lucky environmental impact that produces an adaptive mutation.

Although the mechanism that Piaget proposes is novel, its consequences are fairly similar to the findings of recent research in genetics: There is far more variation than previously recognized. Many or even most genes exist in a number of allelic forms, expressing the biochemical structural variation of which each gene is capable (Piaget 1978). Piaget uses this general biological position as a springboard for reiterating his argument that intellectual activity is a biological function and must follow the same law of organization and adaptation, assimilation and accommodation, as any living system. In his earlier treatise on the idea of phenocopy, he begins with the "Baldwin effect," well known to geneticists: Phenotypic adaptation arising in the individual life history are replaced by changes in the genotype having the same form and the same consequences.

Piaget (1974) drew an important parallel between evolutionary genetic change and cognitive development. In cognition, too, we have phenotypic adaptations, such as imitation, which establish responses that can later be controlled by more fundamental changes in mental structures replacing the ones that give rise to the response, thus consolidating gains made. In this usage of the phenocopy argument, he is quite similar to Kurt Lewin (1935), who also used the terms phenotype and genotype to distinguish between outward behaviors and underlying structures that control them.

The main outlines of controversy have remained unchanged for nearly a century. In 1898, J. M. Baldwin's presidential address to the *American Psychological Association* was called "On Selective Thinking" (Baldwin 1898). He examined "the supply of thought-variations ..., how certain variations are singled out for survival ..., and the criteria of selection" (pp. 1-2). In other words, he used the model of evolutionary theory for a theory of cognitive development. Far from fore-casting chance variation in the role of prime mover, he criticizes this view sharply:

> We do not scatter our thoughts as widely as possible in order to increase the chances of getting a true one; on the contrary, we call the man who produces the most thought-variations a "scatter-brain," and expect nothing inventive from him ... we succeed in thinking well by thinking hard; we get the valuable thought-variations by concentrating attention upon the body of related knowledge which we already have; we discover new relations among the data of experience by running over and over the links and coupling of the apperceptive system with which our minds are already filled. (Baldwin 1898, 4)

Baldwin, of course, did not aim his criticism of blind variation at Donald Campbell, who was not born yet, but at Herbert Spencer, who not long before had applied evolutionary theory to learned behavior in a way that anticipated the behaviorism of 1910-1960. Baldwin went on to explain his theory of organic selection. Some of its highlights are as follows:

1. Mental life, or knowledge, is highly organized: Novelties are assimilated into an enduring structure only if they can be responded to in a coherent way.
2. Of two main phases of the selective function, the first is "intra-organic selection","... this transfers the first selective function from the environment to the organism, requires the new experience to run the gauntlet of habitual reactions or habits which organize and unify the system of knowledges, before it can be eligible for further testing by action" (p. 10).

3. The second phase is "extra-organic selection or environmental selection, which is a testing of the special concrete character of the experience as fitted, through the motor variation to which it gives rise, to bring about a new determination in the system in which it goes" (p. 10). It is this phase in Baldwin's theory that is analogous to what is usually meant by natural selection.
4. Through this highly organized process of variation and selection the individual constantly rebuilds the "platform" on which further experience, action, and growth occur; this means that the variations that occur are not indiscriminate or blind but a function of the individual's whole life history of organized growth.
5. The growth of the internal organization of knowledge "gradually serves to free the organism from direct dependence upon the control of the environment" (p. 21); this means that the whole process of variation and selection becomes increasingly organized and directed as the person matures.
6. Baldwin, like Piaget, who admired him greatly, attempts to show how there could be an "organic logic" governing both biological and psychological growth.

To conclude this brief survey, it can be seen that there is today not one theory of evolution or of evolution and behavior but a wide array of possibilities. This means that the psychologist, as student of this subject, need not be intimidated by the seemingly greater rigor of the natural sciences. It remains true today as it was in Charles Darwin's day, that the study of organic evolution and of behavior can enrich each other.

Theories of the relation between mind and body have always been highly colored by their connection with broad social issues. This is especially true of the history of evolutionary thought, which has been seen as relevant to our understanding and ethical evaluation of war, capitalism, slavery, racism, and sexism. There is, in my opinion, no way of avoiding these connections. It may be helpful to be aware of them, to be sensitive to the social roots of all theories.

On the time scale of history of psychology, a century or so, we see the same issues and theories cropping up more than once, in only slightly altered forms. On the time-scale of intellectual fashion, a decade or so, we see a particular form of argument wax and wane in popularity: in one swing it is the heritability quotient, in another it is the sociobiology of aggression and altruism that is called upon to justify the claim that "you can't change human nature." On still longer time scales, there are always a few voices insisting that we must change ourselves. And the joint evidence of many disciplines suggests "that over the long reaches of evolutionary time, *Homo sapiens sapiens* has changed human nature, that through our own behavior we have indeed made ourselves. The question remains, for the changes we must now make: Have we enough intelligence, courage, and time?

## THE METAPHORICAL STRUCTURE OF DARWIN'S ARGUMENT

A scientific theory has a much denser structure than is generally recognized. Almost every component idea is itself an intricate structure, and the whole is a complex of interacting parts. In constructing the theory of evolution through natural selection, Darwin made use of a number of images or metaphors: tree of nature, war, wedges, artificial selection, tangled bank, and contrivance. Each of these has a specific function in illuminating a part of the theory. These images are not merely didactic or communicative devices, they seem to play a role in the actual generation of the theory: There is a complex and lively interaction between different levels of experience, such as the conceptual and the imaginable.

From a historical point of view, as one theory is assimilated by another, the earlier is necessarily distorted and only partially represented in the latter. As one concomitant of this complexity, while some Darwinian ideas have been assimilated into psychological theories, one basic concept has been neglected. There is in the *Origin of Species* only one diagram. It represents Darwin's idea that in the panorama of nature "organized beings represent a tree irregularly branched," as he wrote in a notebook in 1837. This was fifteen months before he formulated the theory of evolution through natural selection. Darwin used this metaphor in many theoretically productive ways. Yet this conception of fundamental irregularity in nature remains foreign to psychology and other social sciences, which are still dominated by a largely Newtonian world view. Some as yet unexplored implications of Darwin's metaphor have a bearing on the role of the individual in history and on the virtues of "weak theory."

In discussions of the philosophy of science, it has been commonplace to distinguish between the problems of justification and the problems of discovery. The latter can be further subdivided into procedural and substantive issues. This leaves us with a tripartite division: how to know if a proposition, once uttered or formulated is true; how to go about looking for propositions worth considering; and what sort of thing to look for. Within the context of discovery, something has been said about procedural matters. For example, writers in the vein of Hanson (1958) focus on the method of reproduction; writers in the vein of Polanyi (1958) stress intuitive or non-rational aspects of the process of discovery. But substantive matters—what to look for?—have received much less attention. In the older philosophical tradition, discussions of the nature of matter, objects, space, time, life, intellect, morals, humanity, and society were not considered matters for specialists in "other" disciplines but were part of a widespread exchange among intellectuals. This exchange, when it is active enough, helps maintain a general alertness to the mutual import of specialized inquiries and very general conceptions of nature.

The use by scientists of large metaphors and images plays a key role in such discussions, because it bears at once on the procedural and substantive matters referred to in the preceding paragraph. Even when expressed in very general form (vague, intuitive, poetic), such images have generative and regulatory power, both governing the search for more explicit formulations and giving rise to them. When the metaphor is invested with more precise form, it is transformed: We can call it a "model;" it guides analysis and invites the testing of hypotheses. These hypotheses are neither about the metaphor nor about nature, but about relations between them. The testing of hypotheses has been the glory of methodologists, but it remains a sterile glory, so long as little or nothing is said of the primitive roots—both imaginable and ideological—from which testable ideas spring.

Experimental psychologists since the 1950s have become increasingly interested in imagery, but mainly at the level of reproductive images: Either some specific object is called up before the mind's eye, or some imagined relationship between specified objects serves as a mnemonic device, aiding in the recall of previously presented stimuli. The generative role of imagery in productive and creative thinking, unfortunately, still remains outside this universe of discourse. But generative images of wide scope become a central concern when we wish to understand the psychological processes involved in reflecting on the larger concepts of humanity, society, and nature that provide the framework for all scientific inquiry. In an older tradition, however, images of wide scope were not foreign to psychologists. Titchener (1909) begins an important work with an extended description of his image of science as an incoming tide on a sandy, rock-strewn shore.

## THE DIFFERENTIAL UPTAKE OF IDEAS

A fundamental aspect of Charles Darwin's thought has been widely neglected by psychologists, because they are still guided by a highly deterministic view of nature, a simplistic view of science, and a Newtonian hope that their own universe of discourse can be shown to display the same underlying order, simplicity, and harmony that Newton claimed for his.

Although the connection between the tendency toward simplicity and the tendency toward determinism has not received the attention it deserves, a number of authors have drawn attention to the issue in a variety of ways (Sagan 1977; Simon 1969). The late Carl Sagan, for example, pointed out that some 300 million years ago the evolution of intelligence had progressed to the point where "there emerged an organism that for the first time in the history of the world had more information in its brains than in its genes" (p. 47). He estimated, also, that the human brain has some $10^{13}$ synapses and that this permits the brain to assume some $(2^{10})^{13}$ states, concluding:

> This is an unimaginable large number, far greater, for example, than the total number of elementary particles (electrons and protons) in the entire universe, which is much less than $2^{103}$. It is because of this immense number of functionally different configurations of the human brain that no two humans, even identical twins raised together, can ever be really very much alike. These enormous numbers may also explain something of the unpredictability of human behavior and those moments when we surprise even ourselves by what we do (Sagan 1977, 42).

I asked nine social scientists to take a brief test of free association, saying the first word that came to mind when I said the words "Thomas Kuhn." Of the nine, eight responded without hesitation, "paradigm." Upon discussion, all saw the irony that a book entitled *The Structure of Scientific Revolutions* (1962)—equally divided between Kuhn's concept of normal science and of revolutionary science—should elicit such a one-sided response. For completeness, the ninth subject responded: "[Expletive]; *The Structure of Scientific Revolutions*; I suppose you want me to say 'paradigm'."

This differential uptake of ideas has affected the history of psychology and kindred disciplines in a number of ways. The halving of Wilhelm Wundt's work in the received history of psychology contributed to the false hope of constructing a Newtonian science of psychology (Rieber et al. 1980). When the *Origin of Species* appeared, there was considerably greater readiness to draw from it lessons about the inevitability of progress than there was to accept Darwin's theory of the inherently chancy nature of the process (Ellegard 1958; Russett 1976).

Maybe we psychologists trivialize our science by looking too hard and too soon for a few regularities in this diversity. Another strategy might be to find ways of catching hold of the diversity itself, ways of characterizing the unique functioning of each person. This is what Newell and Simon (1972) have in mind when they set about on constructing a theory of the individual human problem solver.

Darwin's thought presents itself in two aspects, quite distinct from each other both in form and in aesthetic tone. On the one hand, there is the beautiful simplicity of the theory of evolution through natural selection. As early as 1838, Darwin could state it in eighteen words expressing the three principles of heredity, variation, and superfecundity, from which, as he saw, natural selection and evolution followed inexorably. On the other hand, there is his fascination with complexity and uncertainty, with nature seen as a multitude of small forces perpetually interacting and changing.

In Darwin's early notebooks and later in his published works, these two tendencies produced at least five metaphors, all of them necessary to express the whole of his thought. After providing some background material, I will discuss these in some detail. For the moment, I want only to introduce the idea that psychologists and other social scientists have been eager to borrow some of Darwin's ideas and imagery, especially the simplifying images of war and artificial selection, which seem to divide the world into winners and losers, or responses into successes and failures. But they have largely ignored the complexifying part of Darwin's thought.

Once it is recognized that organic nature always and in principle involves a dense web of intimately interacting processes, these tendencies toward simplicity appear in a new light. Of course, some simplicities can always be constructed, and it has been and will remain an important part of scientific work to construct them or, if you prefer, to wrench them out of nature. In moving beyond such simplicities, it is enjoyable first to contemplate the richness of the organic world. But it is also our task to search for ways to conceptualize nature in its richness, its variety, its complexity, and its interconnectedness.

It will be helpful to bear in mind the following chronology: Darwin was born in 1809 and died in 1882. The voyage of the *Beagle*, in which he circumnavigated the globe, began in 1831 and ended in 1836. In July of 1837, he began his first notebook on evolution, determined to construct a workable theory and probably believing that he already had the key to it, although this proved not to be the case. In July of 1838, he begin his notebooks on man, mind and materialism. This was an explosive moment for him, for during the same month he also undertook a demanding geological investigation: Rudwick (1982) has shown, this was not merely the narrowly specialized research that it seemed to be but bore directly on Darwin's most general views. On September 28, 1838, Darwin recorded his reading (or rereading?) of Malthus's *An Essay on the Principle of Population* (1826) and his own first excited insight into the theory of evolution through natural selection. I have elsewhere reconstructed the slow growth of Darwin's thinking leading up to that moment (Gruber, 1981e). By November of 1838, Darwin was able to reformulate the theory succinctly in the form of the three principles of heredity, variation and superfecundity. Twenty years later, in 1858, Alfred Russell Wallace wrote to Darwin of his own discovery of the theory of evolution through natural selection, and joint publication of the two men's discovery was arranged. In 1859, finally, Darwin wrote and published the *Origin of Species*. But he remained silent about his views of man's place in nature until 1871, when he published *The Descent of Man*. *The Expression of Emotions in Man and Animals* followed, in 1872. Four of the five metaphors now to be discussed appeared in Darwin's notebooks by 1839 at the latest.

## A PLURALITY OF METAPHORS

Virtually all discussion of metaphor until now has focused attention on the production or meaning of metaphors taken singly: What is a metaphor? How is one made? How do we know whether to call the item we are talking about a metaphor, model, analogy, simile, or image? But when we look at such productions in the context of a full-blown discourse, such as printed text, we see immediately that they do not come singly. Language and thought are permeated with them. It is of little avail to labor over differential definitions, for the idea that conforms neatly to some definition of simile in one paragraph turns up a little later as a particular kind of metaphor, or vice versa. It is not possible to arrive at a definitive count of the number of such productions in a given protocol, because they are nestled and interlaced with each other in ways that do not submit to item counts.

For the moment, then, we need some strategy of approximation. First, although I will continue to use the term metaphor, the reader may wish to substitute some more generous phrase, such as figure of thought. Second, in order to keep the number of figures discussed within reasonable bounds, we will aim for a certain "grain" in our analysis, the rather coarse grain that would appear if we sought for the ruling metaphor of each chapter or major section of a chapter of, say, the *Origin of Species*. Even this grain would give us far too much material to handle in one short essay, so there will be some simplification by some rather arbitrary omissions. The essential point will have been conveyed if the reader comes to see that the ensemble of metaphors working in one human mind, for example, Charles Darwin's, can be very complex indeed.

To these difficulties, I must add one further caveat. When we choose a term to stand for a given metaphor, the choice inevitably masks the fact that the actual idea is captured only by a family of metaphors. For example, we may speak of the metaphor of war in Darwin's thought, but this is only one member of a family that also includes struggle and equilibrium. Thus, there exists not only the "between-metaphor" complication. Nor can we afford the luxury of believing that these are only our own peculiar difficulties, while for Darwin himself there was a "truly" central metaphor, simple, simple and pristine, ruling over all his thoughts. As I will make clear with some other examples, Darwin was at least as aware as we are of the problems of metaphoric construction and choice that he had to solve in order to elaborate and clarify his ideas. And this should not surprise us.

I turn now to the enumeration of and discussion of some of the metaphors Darwin used in moving toward and writing the *Origin of Species*.

### *Artificial Selection*

Darwin was drawn to this subject because of his interest in variation and hybridization. He knew much about plant and animal breeding before September 28, 1838, but it was not until some time after that date that he took explicit note of the similarities between artificial and natural selection. In the *Origin*, he enlarged on this subject early in the book: The analogy between natural and artificial selection was as close as he could come to the application of the experimental method to the study of the process of evolution. By 1859, he could draw on his accumulated experience as a pigeon fancier and on many other strands of knowledge to dramatize the impressive cumulative changes that purposeful human begins could make in other species by selecting for the same trait over many generations. But he was also careful to point out that nature operates selectively not on one or a few favored characteristics but on the whole organism's adaptation to its natural environment and that it operates over immense reaches of time. Thus, his discussion of the similarities and differences between natural and artificial selection served to highlight the importance of cumulative change. Moreover, in the course of that discussion, he introduced a topic to which he devoted a separate eight page section on the "correlation of growth," that is, the way in which the evolving organism remains a subtly coordinated system in which changes in one part engender or favor changes in other parts, in order to maintain this coordination.

*War*

The second human activity that Darwin took as a metaphor for natural selection was war. In this, of course, he was following Malthus, for the first volume of *An Essay on the Principle of Population* is very largely a catalog of human warfare and decimation. The key point for Darwin is the superfecundity principle, that population growth tends to outrun resources necessary for survival and that this necessitates both interspecific and intraspecific struggle. Thus, the metaphor of war served to emphasize the role of struggle in the process of evolution. But Darwin's conception of struggle was not the kind that appears in other theories, not a titanic struggle between polar opposites—good and evil, oppressor and oppressed, Thanatos and Eros. For Darwin, struggle meant the total activity of each organism permitting it to survive long enough to reproduce its own kind. In this struggle the race is not only to the strong and the swift but sometimes to the well concealed, the prolific, the cooperative, the inventive, the adaptable. Since the theory aimed at explaining the evolutionary adaptation of species rather than of individuals, social characteristics of organisms could be flexibly taken into account. For example, sexual selection, the struggle between males of a species for possession of the females, is rarely a struggle to the death, since the defeated male is of potential use to the species only if he survives.

*Wedges*

This is the least known of Darwin's metaphors. It appears in the excited passage in his "transmutation notebook" written on September 28, 1838, and it surveys through various preliminary essays into the first edition of the *Origin of Species*, but it was deleted from the later editions, including the most widely read sixth, and last, edition. In Darwin's phrasing, the wedge image has two aspects. First, he speaks of "one hundred thousand wedges." But this he means to emphasize the point that the forces making for evolution are multitudinous, arising continuously out of the complex manifold of nature. Secondly, he is speaking of these wedges as "splitting the face of nature." This phrase reflects Darwin's awareness of the small but vital difference between a God-ordained, perfectly harmonious order and a world in which small imperfections in adaptation constantly arise, serving as the motor of evolutionary change.

*Tree*

The three metaphors discussed so far all bear directly on the concept of nature selections. The remaining two are more general, reflecting even wider concepts of nature, providing the substratum necessary to think about evolution. Among all his metaphors, Darwin's image of the tree of nature as an irregularly branching tree certainly deserves pride of place. It appears early in the B Notebook (the first of the transmutation notebooks) and is then quickly redrawn to bring out Darwin's thought more precisely (See figures on page 246 and on page 247). Over the years, Darwin drew a number of tree diagrams, trying both to perfect it and to penetrate it—to learn what his own imagery could tell him. In a highly formalized version, the tree diagram is the only figure in the *Origin*, and Darwin refers to it over and over, throughout the book.

It is reasonably clear from the sequence of events that when Darwin drew his first tree diagram he was already a convinced evolutionist and that the diagram expressed his view of a continuously evolving, freshly differentiating organic world. At the same time, he was drawing the tree diagram in order to grapple with a puzzling argument against evolution. If evolutionary change were everywhere continuous, there should be no gaps in the natural order: It should be possible for systematists to construct taxonomies in which there would be no "missing links." So Lamarck had believed, taking as fresh evidence for such continuity every new species brought back by the voyages of conquest and discovery. But others used the many apparent gaps in the system of nature as an argument against evolution; still others attempted to fashion "perfect" taxonomies in which the absence of any gaps would serve as evidence that the panorama of nature as a whole must be the handiwork of a divine artificer. In the tree diagram, Darwin saw another possibility: To be sure, there must be continuity in nature, in the sense that every living thing has a natural history. But continuity does not necessarily require completeness. Beginning from some primitive form, evolution proceeds along diverging pathways; at every branching point, some species that exist are extinguished, and the species that these might have become never can evolve. There is thus a fundamental incompleteness in nature: Not everything that might have been will be.

Secondly, the tree diagram captures Darwin's profound conviction that nature is irregular. Among all those species that might evolve, the ones that do appear arise from happenstance. In some ways, Darwin grasped this point long before he grasped the principle of natural selection. Suppose, for example, members of a species migrate to a new habitat and there are isolated from other members of the species by the hazards of geography and of geological change (e.g., a land bridge used for migration can be submerged by the subsidence of the sea bottom, or a wind blows a seed or an insect or humans in a canoe to a place previously unvisited by that species). If they are isolated long enough, and if they adapt to their new milieu, they will form a new variant or race and eventually perhaps a new species. Darwin could carry the argument this far very early in his theoretical search, for it does not rest on the idea of natural selection. But the argument contains an important new point. The winds of chance, that produce the necessary isolation of a few individuals in a new habitat, are completely independent of the intrinsic laws of development of members of organic species. In that sense, some critical isolating events are accidents and therefore produce a fundamental irregularity in the tree of nature. This chanciness and irregularity, so much at odds with his predecessors' (and most of his contemporaries') search for a regular and harmonious order in nature, was explicit in Darwin's very first drawing of the tree diagram and in the accompanying commentary.

Finally, of course, the tree diagram is the very image of some at first unspecified selection process. Some species are marked off as continuing, others as becoming extinct. A few months later Darwin saw, not too clearly, that the tree diagram was also a model of exponential growth; if this idea is coupled with some constraints, such as a limit on the number of organisms or of species (i.e., the unit of analysis at work in the phase of the theory in question), a formal principle of selection necessarily follows. By formal I simply mean that, although no mechanism is specified, the occurrence of selection follows as a conclusion from the premises.

### *The Tangled Bank*

The last metaphor I will discuss here is the "tangled bank," the image of the intricacy of nature at a moment in time evoked in the celebrated concluding passage of the *Origin of Species*. It is difficult to specify the first appearance in Darwin's thought of this idea because it goes so far back. In the thousands of pages of notes he kept during the Beagle voyage, there is little or no trace of any concern for evolution, but there are many examples of his fascination with the ecological relations among species. Of course, the idea informs Gilbert White's *Natural History and Antiquities of Selborne* (1789), a book Darwin knew very early; also William Paley's *Natural Theology, or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature* (1802), which had excited Darwin during his student years at Cambridge. In a sense, then, the image of the tangled bank is the least specifically Darwinian of all the images I have discussed. But this does not mean that it is any the less fundamental in his thinking. We can get a better idea of its role in Darwin's thought if we compare the three authors just referred to. For White, there is no metaphoric use of this idea; it is the whole substance of his work. For Paley and for Darwin, some part of nature (e.g., the beehive, the tangled bank) is likened to the whole; in that sense we have a metaphor. But for Paley and the other natural theologians, the central point is harmony and perfection in nature and the beauty of the contrivances by which the Creator has achieved this order of things. This is certainly what struck the young Darwin. But for Darwin the evolutionist, the image is transmuted; it is the disharmony and imperfection that become the cutting edges of his theory.

## DETERMINISM IN PSYCHOLOGY

It seems to me that Darwin had a very clear grasp of the relations between the two images, the tree and the tangled bank. One image describes events at a moment in time in one corner of the forest, with hundreds of species and thousands of individuals complexly interacting with each other, producing a kind of micro evolution. Meanwhile, in another part of the forest, something similar is going on, but other organisms and a whole other set of contingencies are involved. From time to time, organisms from these two domains will come in contact with each other. Even though we may be able to speak of some lawful relations within each domain, these laws give us absolutely no way of knowing at what point in their respective evolutions organisms from the two sets will make contact, or what the outcome will be. In this way, the tree of nature becomes fundamentally irregular and unpredictable.

For example, we can "predict" that some early mammals, faced with a shortage of food near the ground and an abundance of foliage at higher elevations either will evolve some mechanism for reaching the available food or will perish. But even we, with our limited intellects, can conceive of many mechanisms by which the unexploited food supply might be attained and nature is far more prodigal than we in its inventedness. There is nothing in our theory that "predicts" the appearance of giraffes in the world. Likewise for the foliage; we can "predict" either that the tall trees will evolve in some way influenced by the fact that no herbivorous mammal has come along to exploit it or that they will evolve in some way affected by the arrival on the scene of the unpredictable giraffe.

In short, we are not talking about predictions at all, but about a point of view that helps us make some sense out of what has happened. The armamentarium of conventional science—creative simplification, hypothesis testing, lawmaking, prediction, and control—are tools to help us in this effort. I believe we can use these tools to better advantage if we keep in mind that in many key respects nature is irregular, non repeating, unpredictable, incomplete, indeterminate, complex, open-ended, and inventive.

Unfortunately, our discipline, psychology, is still dominated by a highly deterministic point of view. There is an underlying belief in a potentially omniscient Being for whom the course of every droplet in the storm would be knowable and for whom the appearance of complexity would be understood in every detail as resulting from the operation of a finite set of simple laws. One might add, if we take the actual behavior of our colleagues as evidence, that they are hoping and searching for a small number of such laws. I do not want to cast the argument in the form of a Hobson's choice between an impossible hyperdeterminism and an obscurantist accidentalism. On some scales, we can all be determinists some of the time. But it does seem unfortunate that so much psychological work is directed by this vector toward simplistic determinism and so little toward concerted efforts to conceptualize complexity. In the space available, I can only mention briefly some of the major symptoms of this tendency.

1. In the heredity-environment controversy, the debate is still dominated by the view that development and behavior are the resultants of fixed entities with fixed properties. Thus, a certain number of "favorable genes" together with a certain "favorable environment" are supposed to lead to a certain predictable result. In contrast, geneticists insist that the significance of each gene depends entirely on its place in the whole genomic configuration and on a developmentally evolving sequence of interactions with the environment. Nevertheless,

many psychologists cling to the belief that there are favorable genes predisposing favorable outcomes. In this connection, I call your attention to geneticist Lewontin's (1976) criticism of psychologist Jensen's misuse of the concept of norm of reaction.

2. In discussions of the causes of behavior, the myth is still widespread among psychologists—and even more widely taught—that stimuli "cause" responses. With the emergence of cybernetic ideas, an fundamentally different approach has been freshly elaborated. As Powers (1976) put it: "Control theory changes our basic conception of human and animal nature, from that of a passive system driven according to the whims of the environment to that of an active system which more often than not drives the environment to conform with its own wishes, desires, intentions, goals, and basic requirements" (p. 2).

   In a machine-worshipping world, once the feasibility of goal-guided machines has been admitted, it becomes possible to admit the reality of goal-guided people. But if this is granted, the system of their interactions (i.e., the social process) becomes largely indeterminate; it is the working out of an incalculable number of interactions. More important than their number, the social system is a highly differentiated, structured system in which some individuals are more important than others. Even more difficult for a highly deterministic approach, the configuration of the system changes form time to time, so that most "laws" of social behavior prevail only within severely limited boundary conditions. In *The Wealth of Nations*, Adam Smith (1937) proposed a theory in which he treated each individual as a social atom of equal value with all other atoms, the system operating according to very simple laws so that the net result is an equilibrium condition, similar to the way physical atoms, operating according to the gas laws, give an elastic container its shape and volume. To our sorrow, we read every day that all social atoms are not equal and that they are arranged in configurations that give some of them almost unbelievable influence over the shape of human affairs. Although it is not necessarily humanity's brightest dream, Smith's mythical free market might be better than today's reality. For better or worse, however, this reality does mean that some purposeful beings can have a greater effect than others on the course of human events.

3. In developmental psychology, all of the most influential theories—those of Freud, Erikson, Piaget—are cast in the form of single developmental pathways, that is, fixed sequences of stages. No matter how dynamic or interactionist a theory may be in other ways, insofar as it is a single pathway model, it is essentially deterministic.

4. In typological and taxonomic efforts by psychologists, what is most striking is the vector toward simplicity. Whole literatures are founded on simple dichotomies, on six-type taxonomies, or on lists of no more than a few dozen traits. Meanwhile, our colleagues in biology think in terms of three million known

> species and an estimated ten million extant species, not to speak of all those that have perished. Or they think in terms of many thousands of gene loci, with a growing number of known or suspected alleles at each locus (Neel 1976).

There is a relation between simplistic taxonomies and deterministic theories that would be worth exploring. As long as the hope exists of reducing the variety of organisms under discussion to a comfortable compact number of types—roughly similar to the 100-odd elements of physics, or even fewer—a corresponding hope remains plausible. We may find a small set of laws governing the determination of each individual's type and then complete the strategy by using the type to explain behavior. But as the number of types approaches the number of individuals, the value of this strategy fades and it becomes incumbent on us to search for other approaches.

Now, you may argue that contemporary psychological thinking, rather than being deterministic, is highly probabilistic. Do we not teach our students that lawful regularities in nature are really statistical aggregates, and do we not insist on the careful use of statistical inference in drawing conclusions about these aggregates? Yes, of course. But the theoretical focus of attention is usually on the mean value or on shifts in mean values caused by some independent variable.

We recognize a kind of probability-in-the-small, but we look for regularity-in-the-large. This works well under certain simplified boundary conditions. In physics, the chancy dance of millions of molecules in a gas-filled balloon leads to certain average values for their collisions with the interior surface of the container, and this produces a highly regular and predictable result: a spherical balloon (if thickness is uniform) of a volume dependent on a few known variables. The essential requirements for this kind of regularity are: a closed system, a very large number of identical elements, and a very large number of equivalent events (e.g., collisions). In human affairs, none of these conditions is ever satisfied, and in living systems in general, only under very narrow ranges of conditions.

In research in population genetics, for example, the chanciness of the evolution of living systems seems to go well beyond the Darwinian image of nature that I have been sketching out. It is now widely believed that the number of variants extant in a population at any one time is far greater than called for by neo-Darwinian theory-greater perhaps by several orders of magnitude. Genetic drift produces much more variability in the gene pool than had been previously recognized (Kimura 1976). (Variants of this kind owe their existence to protection from selection pressure; that is, they are not functionally significant, but as circumstances change, this immunity fades. Hence, the hope is more remote than ever of achieving scientific progress by further refining our already advanced techniques for neglecting human individuality).

The disciplines of scientific and intellectual history and the history of technology ought to be closely related to psychology, especially cognitive psychology, since they also deal with the way human beings get ideas and elaborate them. In fact, psychologists have not paid much attention to these fields, except for a few seminal books, such as Kuhn's *The Structure of Scientific Revolutions* (1962), and some case studies emanating form the psychoanalytic tradition. More serious, the main ideas that psychologists have gleaned from these fields are part of the deterministic tradition I have been discussing: emphasis on the *Zeitgeist* and denial of the role of the individual in history. Justified criticism of the "great man theory of history" gives due recognition to the many less than great contributors and to the complex network of social processes involved in intellectual work; in so doing we need to dismiss neither the less than great nor the great individual. Both are important in shaping history, each in his own way.

If important inventions were inevitable results of massive social forces, we should expect something simple and fundamental to have been invented and disseminated in every corner of the globe where a high civilization has appeared. Yet the whole American continent, from Alaska to Tierra del Fuego, with Aztec Mexico and Incan Peru included, was innocent of the wheel and the wheeled vehicle. The wheel, like all inventions, is really a synthesis, a bringing together of many component inventions. The unique combination necessary for the wheel was not an inevitable consequence of the mere existence of a civilization that could well have used it. High civilization, roads, cities, and so on were not enough to evoke the wheel. A certain rare event, a creative process, was also needed—in this instance, probably the confluence of a number of inventions.

We need to learn to look at such unique events. While, by definition, every unique event occurs only once, there are still a large number of interesting ones occurring all the time. If novelty springs from such events, we need some way of making them part of science, some way of asking: How did this happen? Why is it unique?

Lists of simultaneous and independent discoveries or inventions are often propounded as evidence for the deterministic view of intellectual and technological history. Without questioning the role of impersonal social forces or the occurrence of some such cases, my own work has led me to a certain skepticism. The Darwin-Wallace coincidence is one of the most often cited examples of independent discovery of a scientific idea. Yet they occurred exactly twenty years apart, they were not identical, and they were obviously not independent; when Wallace developed the idea of evolution through natural selection, it was to Charles Darwin and to Darwin alone that he sent his first sketch of it!

We are faced with some difficult conceptual choices. If we could think of living systems as operating through processes linked in one-way causal chains, we could retain a faith in science as the study of deterministic systems without giving up the idea of chance. Chance could operate through the unlooked-for-collisions of previously independent systems (e.g., alpha-particle x gene-mutation), leading to events not predictable from the study of the separate systems.

Accidents of this type, although they upset our predictions, need not shake our faith in the principle of determinism.

But in systems containing a multitude of complex feedback loops (e.g., organism chooses environment; etc.), our ability to predict is affected by the level of analysis at which we decide to work. In the short run, body temperature and belief systems both remain predictably stable, controlled by regulating mechanisms whose adaptive function is to maintain stability. In the longer run, some of us will produce unpredictable creative innovations that will direct the course of cultural and social evolution down (or up?) uncharted pathways. In the far distant but quite predictable future, we will all be dead and our solar system will grow cold. Beyond that, something else will certainly happen somewhere.

## ALTERNATIVES TO SIMPLISTIC DARWINISM

If psychologists want to understand just how the individual relates to society, just how the unique creative product is at once unique, accidental, and a social product, there is one fundamental task they cannot escape; they must look at the individual. They must examine individual cases thoroughly in all their bewildering complexity and learn how to unravel them without destroying their meaning or their uniqueness.

In the field of artificial intelligence, as computers grow in power and humans in skill, complexity becomes more legitimate, and ways of conceptualizing it more urgently sought. A contemporary example is the use of ideas such as "scene" and "frame" in artificial intelligence laboratories. We are far past the point where "bits" or even "chunks" of information are the units of analysis: Many complex images and scenes are stored, and problem solving requires a system for eliciting active exchanges among them. This is not unlike the arrangement of an exhibition at the Museum of Modern Art in New York City; in order to capture the feel of one quarter of Tokyo, Shinjuku, more than a dozen "experience maps" were used (each capturing a different aspects of the place), and no one would really suppose that this fascinating array exhausted the domain.

In a very different way, an article by Estes (1976) represents a cautious move in the same general direction. Reflecting on the chaotic theoretical situation existing in the study of probability learning, he comments: "Evidently, the different models are capturing different aspects of a complex process, some aspects being more prominent in some situations. One would like to replace the collection of locally successful models with one general theory, but this objective may not be within our capabilities. A more feasible immediate goal may be to try to understand why different models are required to deal with different situations" (p. 60). In spite of this bow to a possible pluralism and complexity, the main effort of Estes' paper is only to find the boundary conditions within which the revised, still determinist, model will work.

The scientific implementation of the simplistic-deterministic vision of nature depends on an organization of scientific work into isolated specialties. Within such sub-subdisciplines, a larger view of nature seems a world well lost, narrow boundary conditions for research can be prescribed, and idealized laws pursued in comfort. It is not surprising that some of the criticism of this fragmentation has taken organizational form in such groups as the *Group for Dialectical Psychology* (now defunct) and the *Social Science History Association*. Realistically, however, these are still only splinter groups, and the main trends in social science are far from interdisciplinary or dialectical.

In recent years (i.e., since about 1980), a number of developments related to the issues have been taken up. They are so varied and numerous that only a sampler can be given here.

*The Darwin Industry*

The Darwin industry gets its name for its longevity and productivity. In 1982 in Florence a centenary conference was held in recognition of the anniversary of Darwin's death in 1882. This meeting eventuated in an excellent volume, *The Darwinian Heritage*, edited by David Kohn (1985). This was a collaborative effort: some thirty scholars met and argued for a week, then went home and re-wrote. Scanning the volume today, one gets the sense that we now have at least one case well in hand, or almost. For the crucial years of theory development, 1836-1839, one can get a fairly complete and adequately dense account of what Darwin did, how he did it, and the circumstances under which he did it (see Gruber, 1981e). Those scholars, myself included, who worked with Darwin's notebook had the daunting task of assembling and deciphering his difficult and often cryptic handwritten thoughts. In 1987, however, a monumental task was completed—the publication of the transcribed notebooks of 1836-1844 (Barrett et al. 1987). In 1983 there appeared the first volume of the complete correspondence of Charles Darwin. The series has now reached Volume 9, for 1861. The whole set will probably come to about twenty volumes (Darwin, 1821—1882). There will be much for the Darwin Industry to undertake. For example, there is as yet no thoroughgoing analysis of Darwin's thought processes leading up to the publication of the *Descent of Man* (Darwin 1871) and the *Expression of Emotion in Man and Animals* (Darwin 1872)—certainly nothing comparable to the level of detail and conceptual analysis of cognitive processes one finds in the literature for 1836-1839. Even for the years of the *Beagle* voyage, 1831-1836, there remains much to do. Perhaps as the study of adult creative thinking advances there will be better theoretical and methodological guidance coming from that quarter. Meanwhile, biographies of Darwin continue to appear.

*The Case Study Method*

Some twenty-thirty years ago there was virtually no research literature on the cognitive aspects of creative scientific thinking. Given the inevitable emphasis on processes going on within one mind, there was even some opposition to this kind of research, stemming from a generalized reluctance to accept this seeming individualism. The picture is changing now, and individual thinking processes can be addressed without ignoring the social context in which it occurs. Three good sources for work of this kind are the special issue of the *Creativity Research Journal*, edited by Miller (1996b); another issue of that journal reporting on a conference at the Royal Society of Medicine on creativity in the biomedical sciences, edited by McNaughton (1994);

and the collection of essays edited by Wallace and Gruber (1989). Taken as a whole these works give a sense of what it might be like to "be there" as the creative process unfolds.

*Evolutionary Theory*

By the time Darwin wrote the *Origin*, if not long before, he had settled on the implicit premise that each of the many variations that provide the grist for the mill of selection is a small event. This would account for the exceedingly long time required for organic evolution to arrive at the present state of the natural order. Moreover, large evolutionary leaps (macro-mutations) would threaten the integrity of the organism as a functioning system. This assumption of the smallness of each variation undoubtedly also characterizes most theorists who think of themselves as "Darwinian."

On the other hand, belief in large change is a hardy perennial. This might take the form of emphasis on the emergence of culture, or of language, as well as organic evolution. The idea of "punctuate evolution" encompasses both the large and the small. The order of nature remains relatively stable for long periods of time; indeed, maintaining that stability is the major function of selection. Still, from time to time cataclysmic events—such as an asteroid collision casting a pall of dust over the earth—may produce mass extinctions and the disappearance of whole evolutionary lines. The resulting natural order—ours to live in—may consequently have an appearance of inevitability and even purposefulness that it would lack if we knew much more about what might have been.

From all this theoretical ferment one gets the sense of a new synthesis brewing, its ingredient slowly being combined and assimilated.

No one can pretend to real mastery in every branch of contemporary science and social science. But even ordinary polysensory mortals can keep an ear to the ground and a nose to the wind and stay in touch with general trends over areas much wider than their own specialties. So doing, it is not hard to accumulate expressions similar to my own dissatisfaction with simplistic determinism. In an address in 1974 on receiving the *American Psychological Association's Distinguished Scientific Contribution Award*, Lee Cronbach made a plea for observational studies and greater respect for descriptive results as against hypothesis testing, for exorcising the null hypothesis as too frequently leading to a waste of valuable descriptive data, for sensitivity to weak interactions, for avoiding research designs that conceal even strong interactions, for greater awareness of the boundary conditions within which nomothetic laws prevail, and for some recognition that we are often impotent to specify those boundary conditions. He closed with the following words:

> Social scientists are rightly proud of the discipline we draw from the natural-science side of our ancestry ... Scientific discipline is what we uniquely add to the time-honored ways of studying man. Too narrow an identification with science, however, has fixed our eyes upon an inappropriate goal. The goal of our work ... is not to amass generalizations atop which a theoretical tower can

> someday be erected ... The special task of the social scientist in each generation is to pin down the contemporary facts. Beyond that, he shares with the humanist scholar and the artist in the effort to gain insight into contemporary relationships, and to realign the culture's view of man with present realities. To know man as he is is no mean aspiration. (Cronbach 1975, 126)

If we press home such changes in our images of nature and of scientific knowledge, how might the actual practice of scientific inquiry be modified? I offer a few suggestions, none of them really new but perhaps gaining some new force from the foregoing reflections.

1. *Weak theory.* Learn to live with the reality that the drive for strong and simple theories that make highly deterministic predictions may only lead us down the road to fiasco. Historians of the behavioral sciences could make a real contribution by documenting some of these failures.
2. *Sensitivity to boundary conditions.* Within limits, some deterministic laws are possible. For example, under very specific stimulus conditions, height in the visual field corresponds to distance from the observer. Inquiry cannot stop with discovering such laws. We need to go beyond them in two ways: (a) by determining systematically the boundary conditions within which the laws operate; and (b) by not being too bemused or self-satisfied by the laws themselves. Our whole activity of detecting lawful relations and their boundary conditions is part of a still larger enterprise, forming and reforming our images of nature.
3. *Interdisciplinarity.* Piaget's reaction to uncertainties of the kind this chapter is concerned with has been a whole series of writings, not well enough known, on interdisciplinarity (e.g., Piaget 1973c). Each discipline makes assumptions that are not grounded or groundable within its own mode of operation. In principle, each must depend on other disciplines. One need not be a Renaissance person to pay attention to such relationships.
4. *Invention.* One metaphor that runs through all of Darwin's thought, even before he became an evolutionist, is the idea that the curious organs whose functions he loved to work out are "contrivances." As Darwin understood nature, it does not consciously contrive or invent; he intends a metaphoric comparison with the human activity of invention. I believe it was Einstein who said that we know more than we can explain. By the same token, we can invent things without fully understanding how they work. Indeed, such invention, harnessing the powers of intuition and hands-on knowledge, may play a far greater part in the scientific process than has been recognized. Whether or not we seek universal laws, we can still try to invent new ways of doing things; when we have created a novelty, we can try to understand it. This is how I appreciate the strategy of some workers in the field of artificial intelligence. In a first approximation, forswear the goal of understanding the human mind; be satisfied to invent a machine that carries out some functions similar to those of the mind. Then examine the result for whatever light it may also shed light on the "natural" mind. Considering invention as part of science echoes Marx's aphorism: "Previ-

ous philosophers have only interpreted the world. The point is to change it." Invention (including, of course, social invention) is a form of world changing. Changing the world can be construed as part of our attempts to understand it.

5. *Individuality*. Rather than concentrating so much effort on looking for general laws of human functioning, look for laws of the individual. How does this person work? Cognitive psychology, in particular, needs new approaches to understanding each person as a unique system with its own mode of operation. With some modifications, the same idea applies to the study of particular groups.
6. *Openness*. Give up the effort to characterize the person as a fixed entity. Become far more sensitive both to the changes that are actualized and to those that are just below the surface. Be more accepting of the role of chance in human growth and of interactions among loosely coupled systems.
7. *Humility*. Don't change nature too much. We do not know, and in principle cannot know all effects of what we are doing. It's bigger than all of us ... fortunately.

# CHAPTER 3

## FACETS OF THE CREATIVE PROCESS: INSIGHT, POINT OF VIEW AND REPETITION

We designate as a *facet* any aspect of a case study or creative process that captures the investigator's attention as being worth further examination. Facets are not variables or factors. Neither do they contain a fixed range of values, as variables do, nor are they products of the attempt to reduce the creative process to a few quantitative dimensions.

Facets include any aspect of a creative case that can be made sufficiently distinct to permit intensive study. The concept of *facet* arose out of my concern with speaking about real things that real people are doing; it is intended to bring content back into research on creative processes and individuals. Darwin's enthusiasm for variation as expressed in the exclamation in his notebook "1000 species of roses!" is one possible facet. It distinguishes Darwin's concern for particulars, for example, from Piaget's focus on universals—universals in development as well as universals in thinking. The facets of one case study—or investigator—will not necessarily be those of another.

Facets provide fruitful ways of regarding a case. There is no determinate number of facets worth investigating, however; what is considered as fruitful may depend upon the researcher's interest. Thus, different investigators bring together a plurality of aspects that are remarkable about a certain case. The concept of fruitfulness must also be taken historically. What might appear fruitful at a certain moment in time might not at another.

The topics dealt with in the papers of this section—repetition, insight and point of view—provide some further examples of facets which have been fruitful in my own research.

Repetition, at first sight, seems to be contrary to creativity which is intimately coupled with novelty. However, my work stresses its constructive function, and shows this opposition to be only apparent. Repetition is never just a steady recurrence of the same; by providing slight modifications, it enables the creative individual to explore a certain theme again and again. Without repetition variation will not occur.

Insight can be seen as complement to repetition. Needless to say, the creative process is not just made up of a chain of momentary flashes—but such momentary flashes do happen and they are more than mere epiphenomena. I consider them to be products of temporal transformations, a notion that grew out of my work in perception. Insights can compress thought processes that are stretched over extended periods of time to a few seconds or minutes and can thus provide concentrations of long-term changes in thinking, without denying either the momentary or the protracted. In this way, the relation between insight and repetition becomes clearer: To become insights, thoughts have to be rethought. Insights make the thinker aware of cognitive changes; bringing these changes to the researchers' mind may be one of insights' main functions.

A striking feature of insight is its affective component: It is usually accompanied by strong emotions of excitement and joy. However, the firm conviction of correctness, the feeling of certainty traditionally ascribed to insights is misleading in several respects. First it can be deceiving. Anyone who has experienced a great insight while asleep will appreciate this fact. Second, the certitude may not be there at all. Insights do not necessarily provide answers; it may be keener questions that are discovered.

The third facet explored in this section is the concept of point of view. I investigated this idea in the shadow-box experiments, which were inspired by such disparate sources as Plato's cave and Solomon Asch's studies of group pressure. The shadow-box experiment examines the subjects' ability to work collaboratively to integrate their different visual perspectives of the same object and its shadows. The experiments provide a striking metaphorical link between visual and social processes. To speak of divergent points of view in science means to describe two or more belief-systems as widely differing. The use of point of view to designate belief-systems stresses the fact that changes in belief-systems occur globally throughout the system, not locally where we may first notice them. Modifications in one area can require change within other areas of the same belief system.

Yet multiple points of view are crucial to constructing a larger vision of things; such differences do not have to imply disagreement, but can become a way to see what would otherwise be hidden—the horizon beyond ourselves.

# Creativity and the Constructive Function of Repetition[1]

"The scheme of an action is, by definition, the structured group of the generalizable characteristics of this action, that is, those which allow the repetition of the same action or its application to a new content. Now, the scheme of an action is neither perceptible (one perceives a particular action, but not its scheme) nor directly introspectible, and we do not become conscious of its implications except by repeating the action and comparing its successive results" (Piaget 1966b).

My interest in the psychology of thinking began as a student, when Solomon Asch, who was then editing Max Wertheimer's *Productive Thinking* (1945), used the as yet unpublished text as the basis for a fascinating course. Some years later, when I determined to devote my research efforts to this field, I reread the book. To my surprise, I found that Wertheimer's description of thought processes, while giving the impression of recounting sudden insights, was really silent as to the time it takes to think. Meanwhile, typical laboratory studies of thinking presented the subject with problems that could be solved in a few minutes. How could we assume *a priori* that a life devoted to the most difficult problems is nothing but an intensification or magnification of thinking as it occurs in these laboratory experiments? I began to read the history of science and became more partial to the idea that the most significant aspects of creative thinking involve a process of protracted cognitive development, a subject of which I knew nothing. This led me to Geneva in l956, as I began reshaping an experimental psychologist into someone fit for developmental research, although not in the field of child psychology.

## On the Magnitude and Frequency of "Aha" Experiences

Nevertheless, in 1957, when I studied the thousands of pages of notebooks Charles Darwin had kept during the voyage of the Beagle (1831-1836), my initial hope was to discover one great moment of insight, some miraculously early moment when Darwin (perhaps standing on a rock in the Galapagos Archipelago) had all at once conceived the idea of evolution through natural selection. It was only after a long hard summer of fruitless search that I realized for myself—what Piaget could have told me, if I had been ready to assimilate it—that scientific thought is a slow, constructive, growth process. My task became the reconstruction of the ensemble of Darwin's ideas at a series of points in time.

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1. The author warmly thanks Dr. Christine Gillièron for her helpful comments.

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As I have described in *Darwin on Man* (Gruber 1981e*),* Darwin had not one but many insights. Our interest is therefore drawn to the growth of his ideas through processes of assimilation of novelty, coordination of structures, correction of disequilibria, constructions of new schemes, etc. Thus, the focus of attention in *Darwin on Man* was the changing *structure* of ideas, and not specifically the *process* by which such change is accomplished. In a sense, the focus of attention was still on insight, although the magnitude of each insight considered had been scaled down from the earth-shaking, once-in-a-lifetime event to the sort that occur far more frequently.

Additional support for this view comes from a ten-year record of scientific work kept by an experimental psychologist whose primary area of interest happens to be visual research (Crovitz 1970). During this period he tried to write down everything, doggedly making over 30,000 entries in his notebooks, of which 680 were flagged at the time entry as “sudden illuminations.” This number comes to approximately one per week, and the author tells us that his insight-rate was somewhat lower during one long period and somewhat higher later on. It should be stressed that the occurrence of 680 sudden illuminations in one person’s scientific work changes our very conception of insight. This large number suggests that moments of insight are expressions of the relatively stable functioning of a system, rather than of its overthrow.

Suppose for the sake of argument, then, that Crovitz’ account is typical: insights at the rate of one per week, and other events worth recording at the rate of fifty per week. We must also grant that a more complete record might be far longer; Proust would probably consider Crovitz’ 30,000 entries a mere sketch.

Every creative thinker wants to have great new thoughts, discover new things, but he spends most of his time doing things he already knows how to do rather well. Thus for a scientist: repeating an experiment with perhaps some minor variation, running over a familiar proof, reading an article containing no major surprises, explaining his work to a colleague, listening to a colleague do likewise, etc. And similarly for other creative workers.

Although this is routine, it is usually far from boring. Although it is repetitious, nothing is ever repeated exactly, a point which Bartlett (1958) has made very convincingly. This kind of routine is in fact what Piaget might call the exercise of schemata.

## ON THE CONSTRUCTIVE FUNCTION OF REPETITION

All fundamental life processes are highly repetitive. Most growth and change comes about through the repetition of relatively stable processes. Of course, in order for the previous sentence to make sense, repetition cannot be thought of as simple and exact: variations must occur and these (or some of them) must provoke changes in the structures regulating the processes. But these variations would not occur in the absence of a stable, repetitively functioning system. Thus, constructive developmental change is the direct result of the repetitious exercises of existing schemas.

Psychologists have not been particularly interested in this constructive aspect of repetition. Even Piaget (1952c) has referred to it and described it primarily in his examination of infant development, i.e., the sensori-motor period. In the main work of the Geneva school on the period of concrete operations, the child is typically presented with a problem-like situation, and his solutions and understanding of the problem are investigated. The occasional use of repeated administrations of the same test or problem do not constitute an exception, since the number of repetitions is usually only two or three; what is more important, the conceptual focus of such studies is not the role of repetition in growth, but the occurrence of growth itself over the lapse of time between tests. Thus, even in Geneva, a central Piagetian idea about the causes of growth has not been thoroughly investigated.

The more general problem-solving literature reveals a preoccupation with the *first* appearance of a given response (i.e., "the" solution to the problem). Indeed, it would hardly make sense to most investigations to administer the same problem repeatedly, since the topic is problem solving, and once a problem is solved it loses its status as a problem. Even more generally, this approach to adaptive growth puts all the emphasis on what the behaving subject does *not* know how to do: when he is confronted with a problem, various activities take place until a successful adaptation is achieved.

But we ask, do problems occur very often? Does adaptive growth only occur when problems arise? Another picture of development might be drawn as follows: the organism spends most of its time doing things it knows how to do well; it does them repetitiously; indeed, it seeks out situations in which it can behave in this way and avoids situations in which it cannot; nevertheless, adaptive growth occurs.

Although there are various exceptions that might be argued, the fact remains that the modal activity of the organism is to do things it can do well. In the *Origins of Intelligence* Piaget examined the various forms that this activity takes in a baby. While it is true that subsequent development leads to new and higher forms of mental activity, there is no evidence that secondary and tertiary circular reactions ever disappear from adult human behavior.

Previous studies of psychological changes resulting from repetitive activity have focused attention on the disorganization of behavior and experience consequent on extremely prolonged and unvarying repetition. Classic examples of such research are the studies of lapse of verbal meaning when a word is repeated many times, and the work of Kurt Lewin's student, Karsten, on psychic satiation (Karsten 1928; see also Lewin 1935). In these latter experiments the subject was required to repeat an activity, such as drawing a simple design or reciting a poem, with no end in sight, that is, *ad nauseam*. Very striking examples of deterioration of behavior were produced. But even in such situations, in the early stages of the experiment, it was noted in passing that spontaneous variations occur which we might now consider constructive, or primordially creative.

## THE QUASI-REPETITIVE EXPLORATION OF A DOMAIN

We have recently begun to explore constructive functions of repetitive activity in adults.

In our laboratory we have begun using the approach of translating problems which are first brought to our attention by the case study method (which is a special case of developmental research) into experimental form, in the hope of contributing something to the synthesis of developmental psychology and general experimental psychology. The following experiments with adult subjects on the constructive function of repetition have only just begun and do not merit more than the brief account necessary to show that an experimental attack is feasible.

In one type of experiment[2], we are interested in how the subject explores the domain of number when asked to generate sets of five numbers. For half the subjects, the instructions mentioned that we were interested in performance in a repetitive task; for the other half, the instructions mentioned that we were interested in how people vary their responses. This difference in instruction did not have much effect, although it is true that of our seventy-two subjects, the only one who gave absolutely unvarying responses (the numbers l, 2, 3, 4, 5 in each set, until asked to stop) was in the group with instructions mentioning repetition. On the whole, the task as interpreted by the subjects should be called *quasi-repetitive*, since the most striking characteristic of the subjects' behavior was their spontaneous tendency to use one procedure to generate sets of numbers for awhile and then to switch to another procedure. Occasionally, the subjects attempted to generate random number series. We know from other studies that this is impossible. But the present study permits us to add the point that a subject spontaneously varying his procedure for generating sets of five numbers would not always be easy to distinguish from someone trying to produce sets of random numbers.

Some of the methods used by our subjects for varying the sets of numbers include: arithmetic series, geometric series, reversal of a previous set, personally meaningful numbers (telephone, birth-dates, etc.), changes in order of magnitude, changes in type of number (e.g., use of negative numbers, exponents, etc.). To our surprise, most of the subjects found the task interesting and even challenging. A very simple observation is of some interest. The typical subject wrote his responses at a rate about one half to two third as fast as the mere mechanical writing of the same digits would require if some completely unthinking routine were used (such as all numbers from one to one hundred in groups of five). From the evidence we have presently available, subjects in this experiment do not hit their stride until they have written about twenty groups. Their early productions tend to be quite routine. But after writing some twenty sets of five numbers, i.e., working for about two to three minutes, the typical subject begins the process of response variation described above.

2. In cooperation with C. Burns, M. Moore-Russell, J. Simeon, and R. Simoneit.

Some subjects can go on producing varying responses almost indefinitely, others seem to fatigue, or to exhaust their repertoires, and relapse into more stereotyped performances after fifteen to twenty minutes (i.e., about 150 sets of five numbers!).

Since our subjects had little mathematical training, the sets they produced were relatively simple, of no great mathematical sophistication. It is all the more interesting that with such subjects this quasi-repetitive task generated so much interest and thought, and so much intra-individual variation of response.

In another experiment,[3] the subjects were asked to generate number series (they were given the example: 2, 4, 6, 8 ...) for ten minutes. They were further asked to make a mark next to any series that they found particularly satisfying. The most interesting results are: Subjects tended to generate series of the same type for a while, and then switch to another type. Within any such cycle (consecutive series of one type) the series increased in complexity, either by increasing the magnitude of the numbers used or by complicating the generative rule employed. Almost invariably, whenever a subject marked a series as particularly satisfying, that series was the last in a cycle, although not all cycles ended with such a "mini-aha-reaction."

In these experiments, although our initial intention was to explore the repetitive exercise of a single schema, it is reasonably clear that the subject brought many schemas to bear on the task. It might be better to speak of the behavior under scrutiny as *quasi-repetitive exploration* of a domain. This may well be the typical case, since a single schema is a theoretical abstraction and real behavior is probably rarely regulated by only one schema at a time.

In both of these experiments it would be difficult to specify the "stimulus" to which the subject was responding as any external event. But there are interesting cases where the same stimulus is presented repeatedly, and the subject constructs and reconstructs his response to it, i.e., explores the domain of possible responses.

A familiar case is listening to a piece of music repeatedly, enriching one's grasp of it on each encounter. To study this type of process, we have begun showing the same brief film to subjects repeatedly.[4] For the moment, all we can say is that the occurrence of such construction and reconstruction is very evident. In the first few seconds of viewing, the subject begins to develop a scheme into which later sequences are assimilated. On re-viewing the film, new themes may emerge, new details may be noticed, and the scheme may be modified considerably. The particular film we use admits of marked variations in interpretation, as evidenced by inter-individual variations. But a given individual rarely makes such a large change. We have not, however, pressed this line of work very far, and it will be of great interest to discover how the subject sometimes breaks through the confines of one regulatory scheme and radically reorganizes his interpretation. Can, for example, constructive repetition alone produce this result, or must other factors be called into play?

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3. In collaboration with R. Reynolds.

4. The film we use was made by F. Heider and M. Simmel. See Heider and Simmel (1944).

## THE RICHNESS AND DENSITY OF PSYCHOLOGICAL OBJECTS

Naturally, discussion of repetitive behavior brings to mind studies of learning and memory, especially rote learning. It should be stressed that we have been discussing something quite different. The conceptual focus of attention in most studies of learning is how the subject does the same thing better and better. Enormous experimenter ingenuity is often expended on guaranteeing that the response will be unambiguously elicited by the same stimulus and repeated, so that it can be studied in its stereotyped splendor. But in the quasi-repetitive exploration of a domain, or in the exercise of a schema, the subject never does the same thing twice: in our studies of such behavior we are interested in the *joint* occurrence of variation and repetition. Indeed, to explore any domain, both are necessary: constructing a map obviously requires moving to new loci, but it also requires retracing one's path. At least vicariously, we must return to some point of origin or other landmark, and begin again.

Until recently, most studies of memory were based on what amounts to a *copy theory* of memory: the material to be remembered was presented repetitiously in the same way, and the subject's task was to reproduce it exactly. Thus, any constructive activity on the part of the subject was masked by the experimental aim and design. With the revival of interest in mnemonic processing, many investigators now attend to this constructive activity, but there is only limited interest in the way in which this *varies* with repetitive performance; indeed, many experiments on mnemonic processing involve only a single trial. This means that the way in which a person explores a domain by means of repetitive activity with small variations is neglected. The experimental material is chosen accordingly, so that the subject can adequately examine and "mnemorize" it in a single trial.

Thus, research on learning and memory is based on data which is thrice impoverished: the stimulus materials themselves, the subject's opportunity to explore them, and the experimenter's examination of the responses. But suppose one imagines a world in which objects or groups of objects are so complex that they can only be explored by repeated examinations and making of relationships; suppose further that a response is not learned nor material mastered until it is grasped in a manifold of such relationships; finally, suppose that the subject can only construct such a manifold in the course of repeated opportunities to confront the material. Then the constructive function of repetition would come into its own as a necessary field of enquiry. One of Piaget's very great merits, one that has not yet had its full effect on psychology, is to have lain the basis for understanding how it is that all psychological objects are of this kind.

# On the Relation between "Aha Experiences" and the Construction of Ideas

There are two seemingly opposed approaches to creative work. One emphasizes sudden moments of insight, dramatic reorganizations of ideas—the *Aha Erlebnis*. The other emphasizes the slow construction of ideas, treating creative thinking as a growth process. Should we think of the "act" or the "process" of creation?

Three different approaches to this question come to mind: (a) these two ideas are opposed and mutually exclusive; (b) they simply represent different poles of a continuous spectrum of possibilities; (c) they are complementary ideas and we need to consider in some detail the manner of their articulation with each other. The third possibility is the one I wish to explore. My aim in this essay is to open the way to a closer examination of an intriguing subject, still shrouded in mystery but perhaps now permitting some demystification—the *Eureka experience*. I hope to do this by examining both the inner structure of seemingly sudden illuminations and the way such mental events are part of a larger process of purposeful work.

It has been said that creativity requires one or more of the "three Bs"—the bath, the bed, or the bus. In this essay I examine three famous B-Stories—Archimedes's, Kekulé's and Poincaré's—and some others. In the course of the essay, from time to time I step out of my role as student of cases of creative thinking and revert to my former role as experimental psychologist, since any discussion of the *Aha experience* must inevitably deal with events on a rather short time-scale, not ordinarily seen as relevant to historical enquiry. It would be well to know at least a little about how much time is involved. We may then ask more plausible questions about what might happen in that time.

There are three main aspects to a description of the time-course of the type of event we are discussing. *Frequency*: how often do sudden illuminations occur—once in a lifetime or three times a day? *Speed*: how long does a single thought process, such as one insight take? *Duration*: if insights are not rare, the possibility arises that a number of them are strung together in a meaningful sequence; this raises the question of the duration of such a sequence. As will become clear I believe that such sequences typically have durations of months and years. If the term *duration* refers to the *genesis* of ideas, *speed* may be said to refer to their *microgenesis*. This usage conforms with the distinction that has arisen between genetic psychology and experimental psychology. These two sub-disciplines focus on genetic and microgenetic processes respectively.

As soon as we raise the question of the connection between events on these two time-scales, we are faced with the problem of intentionality. Clearly, the weaving together of a series of brief acts into a constructive growth process depends on and

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reflects the thinker's evolving organization of purposes. While that topic is not the focus of this essay, subjects reporting on their own insights do sometimes discuss their intentions. This was the case with Poincaré whose ideas are treated below.

Most treatments of *Eureka experiences* deal with the phenomenon as though (1) they are very rare in the life of the thinking person, (2) they are very rapid, like a millisecond flash having no inner structure, and (3) they are singularities, marking a rupture with the past. But there is some evidence that a thinking life is characterized, not by a few sudden insights, but by a large number of them. If there were as many as two per week, that would be one thousand per decade. In such a case, the more-or-less steady occurrence of insights might be conceptualized as the expression of the functioning of a growth system, rather than a set of singular experiences.

This was one of the central points that emerged from my study of Charles Darwin's notebooks (Gruber, 1981e). His thinking could be described as a process of purposeful growth organized into a number of distinct enterprises. These enterprises moved forward more or less in parallel. Within each, he had many insights. To be sure, he was looking for a way of synthesizing these efforts, and he did indeed on September 28th, 1838 have one great insight in which he first saw clearly the theory of evolution through natural selection. But there are several important ways in which this observation must be qualified. First, his notebooks show that he had or almost had the same idea a number of times before, during the fifteen months of deliberate effort leading up to the moment in question. So the historic moment was in a sense a *re*-cognition of what he already knew or almost knew. Second, the moment is historic more in hind-sight than it was at the time. After having the idea, Darwin reverted to other preoccupations. It took about two more months for the idea of evolution through natural selection to begin to dominate his thinking. Third, the idea when it came did not represent a rupture with his past, but a fulfilment of his own abiding purposes and in this particular case, also a fulfilment of a family tradition. Historically, or on a time-scale of decades, we can see how the appearance of a successful theory of evolution marked a great step in human thought. But individual and society are not simple reflections of each other. Finally, the insight of 28th September has the earmarks of a complex, internally structured event. As Darwin recorded it, at least three modalities of thinking were entailed: visual imagery, internal dialogue, and logical reasoning as well as the transformations of ideas from one to another of these modalities. The case of Darwin is a prime argument against the "one-great-insight" notion. His notebooks are studded with excited passages; he had the same or similar insights repeatedly; he had to have a number of quite different novel ideas and coordinate them in a coherent theory; and whatever transformative moments occurred did their work slowly, thereby expressing their complex inner structure.

A well-known experimental psychologist has furnished corroborative evidence in support of the view that insights occur not singly but repeatedly in a scientific life. Herbert Crovitz kept a log of his scientific work over a ten year period (Crovitz 1970). Whenever he had an "illumination" he starred it. They occurred at a rate of two per week and three per week, in different phases of his life. From reading Darwin's notebooks, and feeling that I know his thinking well, I would judge that Darwin had as many as one per day that would have been worth recording, or between 300 and 500 per year. It might be argued that these were not all "great" insights. True enough, but that is a judgment for history to make, including in historical thought the creative individual reflecting on the road he has taken. In the heat of the moment, small advances *feel* great, and ones that turn out to be crucial may slip in quietly.

We know almost nothing about the microgenesis of scientific thinking. Retrospective accounts of scientists' insights form our main source of direct evidence. Autobiographical accounts on which great reliance has been placed were not set down until years, even decades, after the event. But our knowledge of the fading of such memories suggests that much, perhaps almost everything, is lost in such delays. In trying to make some approach to the inner structure or microgenesis of insights, I have drawn on two sources: evidence about related processes that have been studied by experimental psychologists, and as careful as possible a rereading of some of these retrospective accounts. In addition, I have been guided by self-observation having kept notes on my own thought processes during the last two years. But these will not be reported here.

Most experimental work on the time elapsing during various psychological functions is quite specialized. We have no direct empirical answers to some important questions. But we probably know enough to reject the idea that sudden illuminations —*Eureka experiences*— happen in a millisecond flash. I have collected in Table 1. some "off the shelf" results.

*Table 1.* Response time for various psychological functions

| | |
|---|---|
| Simple reaction time to light, sound, touch | 150-200 msec |
| Take in familiar monosyllabic words | 300 msec |
| Fill in the last word in very simple predictable sentence | 500 msec |
| Imagine a tiger | 1-2 sec |
| Form association useful in later recall | 2-5 sec |
| Recognize a fragmented picture: | |
| if looking for it | 3-10 sec |
| if not looking for it | not at all |

Suppose it takes about five to ten seconds to "think" a fairly simple thought for the first time. Suppose also that it takes only two to three seconds to "feel" the thought, that is, to have the particular emotions peculiar to that thought for that person. Someone could begin to have a dangerous idea and feel that he was going in a dangerous direction before he had the thought quite formulated. He could even decide to discontinue it, or simply veer away from it the way one does from danger while driving a car. In a sense, then, he would never have had the dangerous thought. Another person, with a different style, could rush toward the idea precisely because in embryo it felt dangerous, exhilarating. Still another person might think faster than he feels and collide with the idea before he sees the danger in it. For someone operating in a different ideological and social framework, the idea might hold no terrors.

Although all sorts of patterns are possible it is reasonably clear that meanings do not occur "instantaneously," and there is, consequently, time for the thinking person to manoeuvre, to steer his thoughts in desired directions and to avoid undesired ones. This proposal is not entirely speculative. There is by now a body of experimental literature suggesting that the rise of emotional response may precede the coming into conscious awareness of the contents to which the person is responding (Zajonc 1980). These results have been obtained in experiments dealing with perception of taboo words exposed briefly, in experiments calling for preferential judgments, and in experiments on forming impressions of persons (Hoffspiegel 1980). Why should not the same possibility exist in the construction of a new idea?

Most of the experimental evidence deals with single acts, that is, one response to one stimulus. But we are interested in the time it takes to think, which might mean a train of related ideas. The dean of American experimental psychologists, Robert Woodworth, found an experimental way of estimating the rapidity of dream-like reveries. He concluded that in a *train* of images, the individual images might take as little as 0.25 seconds. A very simple dream he discusses was composed of about sixteen images, which could be grouped into four scenes, taking about three or four seconds for the whole dream. Woodworth (1897) also observed that subjects re-living "a large segment of experience," such as a trip, with a feeling of instantaneity, might take between five and sixty seconds.

Concern for the duration of larger sequences of thought was a major theme of my work on Darwin. In bringing it up here, my main aim is to point out the necessity to think of intellectual work on several time-scales. This is not merely a convenient abstraction; it corresponds to the person's phenomenal organization of work. The working individual divides his thought into moments, episodes, projects and enterprizes. Each such scale has meaning for the person. To understand how his thinking is organized, we must understand its temporal structure. This idea will reappear in the cases I now take up.

## ARCHIMEDES

The name "Eureka experience" derives from the famous story of Archimedes in the bath. Supposedly he noticed the rise in water level he entered the bath, and realized that the amount of water displaced would be proportionate to the volume of the object immersed: a true gold crown would have a smaller volume than one in which baser metals had been mixed.

But no less a psychologist than Galileo insisted that this story was implausible (Galilei 1961). First, it would not give the mixture of gold and silver in the alloy actually used in the crown; the result would be far cruder than needed. Second, from his knowledge of Archimedes's other work (especially *Floating bodies*) Galileo perceived the solution that would been readily available to his forerunner: the use of a special balance for measuring density by measuring what proportion of its weight in air a body loses in water. Galileo even went on to invent an exact way of measuring the position of the counterweight on the beam. While his technique need not concern us here, it is interesting to note that Galileo thought Archimedes would have thought like him. The most important point, that Galileo saw Archimedes's solution as growing out of longstanding concerns and a highly elaborated point of view, is reflected in more recent studies of Galileo by Drake (1978) and by Hooper (1979).

The trouble with the legendary version is its crude empiricism, suggesting that Archimedes actually learned about displacement at the moment of stepping into his bath and thus "saw" the solution. Galileo's more constructivist account need not be read as altogether excluding the influence of the bath experience. Archimedes may have often seen and thought about the water displaced by his body. If at the moment in question he was in mid-course in constructing a new set of ideas and a solution to a new problem (i.e. in the manner Galileo proposed), then the sight of displacement would be assimilated or mapped into a different schema than before, and the act of assimilation would provoke new accommodations. Even the simple act of submerging an object in water has many subtleties. Which ones are picked out and exploited depends on where the thinker is at the time. We can accept Galileo's sophisticated caveat without denying the import of the bath, so long as we remember that Archimedes was immersed in thought.

But this founding incident must remain shrouded in doubt. The first record of it we have available was written by Vitruvius, about three centuries after Archimedes died.

## KEKULÉ

Let us turn now to the case of Kekulé's dreams and reveries. No creative person's subjective account of his thinking could seem to provide a more dramatic instance of sudden illumination born of strong contact with freely flowing primitive processes of the unconscious mind. In 1854 Kekulé had brought out a seminal paper, the first publication indicating his structural approach. Recollecting the work he did then, Kekulé wrote:

> During my stay in London I resided for a considerable time in Clapham Road in the neighbourhood of the Common. I frequently, however, spent my evenings with my friend Hugo Miller at Islington, at the opposite end of the giant town ... One fine summer evening I was returning by the last omnibus ... I fell into a reverie [Träumerei] and lo, the atoms were gambolling before my eyes! Whenever hitherto, these diminutive beings had appeared to me, they had always been in motion; but up to that time I had never been able to discern the nature of their motion. Now, however, I saw how, frequently, two smaller atoms united to form a pair; how a larger one embraced two smaller ones; how still larger ones kept hold of three or even four of the smaller; whilst the whole kept

> whirling in a giddy dance. I saw how the larger ones formed a chain, dragging the smaller ones after them, but only at the ends of the chain .... The cry of the conductor: "Clapham Road," awakened me from my dreaming; but I spent a part of the night in putting on paper at least sketches of these dream forms. This was the origin of *Structurtheorie*. (Kekulé cited in Rapp 1901)

Arthur Koestler comments on this passage: "The whirling, giddy vision reminds one of the hallucinations of schizophrenics, as painted or described by them. Kekulé's case is rather exceptional, but nevertheless characteristic in one respect, the sudden abdication of conceptual thought in favour of semi-conscious visual conceits" (Koestler 1967, 170).

And yet it seems to me that a different story can be read in Kekulé's memories, a story of the evolution of a point of view, of protracted purposeful work, and of the growth of a highly specialized mental language, or modality of thought. Of course, there were at least two moments, but probably many more, something like the two accounts Kekulé gave in his autobiographical address. But these instants did not come out of the blue, and in order for each to do its work, he had to seize it and make it a part of the project he was pursuing.

Kekulé's recollections were included in an address he gave in 1890, decades after the events described. The second reverie he recounted, leading to the hypothesis of the benzene ring structure, occurred eleven years after the first, in 1865. Let us put aside any questions we have about the fallibility of memory for such subtle events. Here is one of the first minds of the nineteenth century reporting on itself. There must be some important connection between Kekulé's thought processes and his description of them.

It should not be thought that Kekulé "saw" the real structure of the benzene ring. He got a very general idea of a ring structure, an hypothesis as he called it himself, an idea that could be realized in numerous ways, as subsequent controversy showed. Kekulé's description of his thinking suggests that it would be natural for him to perceive more than one of these possibilities, and he did so, using at least three different visualizations in 1865-66.

Hein has given a clear account of Kekulé's visual thinking. It was, he says, probably strengthened and focused by his early training as an architect. It was not merely a modality of thought, but was bound to Kekulé's view that a model should be more than a formal accounting for a set of valencies. It should give an idea of how "the atoms of a polyatomic molecule are arranged in space so that all the attractive forces are satisfied." In spite of various formulations, Kekulé's main emphasis was on hexagonal configuration in a plane. Some writers interpret this, as meaning that Kekulé thought in terms of two-dimensional space. A more plausible interpretation is that he thought of chemical structures in general as lying in three dimensional space, within which, of course, some planar configurations are possible (Hein 1966).

Farber writes of Kekulé's "dreamlike vision" as though it were an extraordinary event in Kekulé's life and the point of departure for his later thinking which merely elaborated the original insight (Farber 1966). In contrast, I want to advance the idea that Kekulé's visions were not unusual for him, but were the way he thought. His dreams or reveries were extensions of his waking thoughts. The ideas he developed were part of a complex chain of events.

In examining more closely Kekulé's account of the 1854 reverie, four points stand out. First, we notice that the type of imagery he describes was by no means new to him ("Whenever, hitherto ... up to that time ..."). We have here, not something totally new, but a variation on a theme. William Wordsworth could think directly in iambic pentameters, John von Neumann directly in mathematical equations (Heims 1980), and Dr. Johnson undoubtedly directly in prose. Kekulé had evolved a special form of imagery in which he could think directly; he had already had many ideas in that modality: and now he had a new one.

Second, it is clear from the record of Kekulé's life and from his recollection of 1854, that he had many occasions to move back and forth between his personal imagery and other forms of thought, and that in this way he went on thinking about and elaborating *Structurtheorie* ("I spent part of the night in putting on paper at least sketches ...").

Third, the way the tale is told strongly suggests that the thought process was no millisecond flash, but a process somewhat extended in time. To get some estimate, however crude, of the elapsed time of Kekulé's thought, I have tried re-enacting it myself. The crucial part the new idea (beginning with "Now, however ...") seems to take between ten and fifteen seconds in my kinaesthetic imagery. Also reducing the idea to a telegraphic form that might be the verbal minimum for a verbal thinker, and reading rapidly, I find it takes about ten seconds in silent reading and about fifteen seconds aloud. All this refers to a single sequence of events. But Kekulé is clearly describing a repeated phenomenon. So it may be reasonable to guess that the original visual thought process took him longer.

Fourth, as so often happens when thinking goes well, it has a twin character of objectification and spontaneity. The dramatist's characters talk to each other—in his head. Kekulé's atoms gambol before his eyes. As with any highly practiced skilled act, it runs itself off effortlessly and spontaneously. It seems to happen "out there," yet remains under the control of the thinking, acting person. The tennis player puts his shot where he wants it and says "my backhand is working well."

But this double quality of objectification and spontaneity should not lead us to forget that the flow of imagined acts, words, and scenes remain the thinker's thoughts, they remain under the control of the larger cognitive systems he has evolved. If "they" start doing something he does not like, he stops them, or changes their course. Moreover, even in a versatile person, they remain within their proper domain. Kekulé's atoms do not become tennis balls in an imaginary game, or characters in a play, or even atoms in Brownian motion. Because they are Kekulé's, they explore the structural possibilities of chemical knowledge.

Nor are the different modalities of thought separated by an unscalable wall. Thinking moves from one modality to another, from visual images to sketches to words and equations explaining (that is, conveying the same meaning as) the visualizations. The thinker is pleased to discover that certain structures remain invariant under these transformations: these are his ideas. These transformations are essential to thought. Without them it would be closed in a solipsistic prison. Dialogue, both internal and external, is a ubiquitous part of the process. By 1860 *Structurtheorie* had reached the point where Kekulé and others organized an international congress to consider ways of determining valencies.

Kekulé's thought process must be seen as inserted in historical time-ranging perhaps from Faraday's discovery of benzene in 1827 to Kekulé's recollections in 1890. On that time-scale there was a highly social process of collaboration, controversy, and dialogue. Kekulé was a part of that history, lived it, and knew it. His private thoughts were extensions of that historical process, a part of that extended dialogue. His active role in constructing *Structurtheorie* occupied a considerable part of the range. If the moments of rapid change in thinking, occurring in the privacy of one person's mind, are a part of a social process, the transformation of ideas from private to public modalities of thought must be an indispensable part of each significant event. Unfortunately, so much attention has been given to modalities of thought and experience taken singly—such as visual imagery or language—that we know very little about these essential transformations. Instead of doting on or quarreling over the importance and dominance of this or that modality, studying these transformations might become a very fruitful area of collaboration between historians of science and psychologists.

We need also to ask, how does Kekulé know that he has had a new idea? His illumination when it occurs, immediately strikes him not only as a solution, but as novel. The meaning is plain: he knows—and deeply—the state of the art. His recognizing the new idea as new for him means that he has a mental record of his own previous moves. Similarly, he must have some sense of history. To know what is new for others, he must perceive the significance of his own thinking in that historical context.

## FREUD

In a celebrated letter to Wilhelm Fliess, written on June 12th, 1900, Freud gave a highly condensed version of the origin of his major work, *The Interpretation of Dreams*. Freud wrote: "Do you suppose that some day a marble tablet will be placed on the house [a house he had just revisited], inscribed with these words: 'In this house on July 24, 1895, the Secret of Dreams was revealed to Dr. Sigmund Freud?'" (Freud 1954, 322). This fragment could easily be read as a neat example of a recollection of sudden great insight, and it certainly conveys that impression. Yet even a cursory knowledge of Freud's work reveals rather a different picture. His work on dreams was part of a huge nineteenth century literature on dreams. In the 1880s he kept a notebook on his dreams. In 1882 he wrote to his fiancée, Martha Bernays, about one of his dreams, giving a pretty good capsule statement of the wish-fulfilment aspect of his emerging theory. In several of his papers published before July 24, 1895, there are discussions of dream interpretation. After that date he continued to revise his theory. So Freud's revelation turns out to be a good example of the process of protracted construction in scientific work.

Yet he did refer to July 24, 1895, as some sort of turning point. What was new? Far from being a sudden blinding flash, it was the first example of a complete analysis of a dream. This was Freud's own dream, "Irma's Injection." The interpretation of the dream itself runs to twelve pages. What seems to be novel, then, is the methodical completeness of Freud's work (1955). The interpretation reads more like Poincaré staying up all night to work out a proof than like a millisecond "Eureka Experience."

Freud himself put one possible relationship between the slow and fast phases of discovery very well when he wrote, at the end of his interpretation of Irma's dream, "*When the work of interpretation has been completed we perceive that a dream is the fulfilment of a wish*" (p. 121). The fast phase is a summation of work already done, a re-cognition. Important summaries are often overtures to new phases of work, and in the end all that may remain in memory is a series of such summaries.

Anyone who reads Freud sees that here is a man who has many many insights. What is more important, Freud perfected a set of techniques, held together by a growing theory, both for generating new insights and for pursuing them. Freud's own work and thought seems almost a perfect illustration of the *evolving systems approach* to the thinking of a scientist.

## POINCARÉ

Henri Poincaré's essay, *Mathematical Discovery* (1952), is one of the best known, widely cited and often reprinted accounts of what seems to be a *Eureka experience*. Arieti, for example, while sceptical of the psychological value of Poincaré's explanation of the event, accepts the account without question: "At the moment he put his foot on the step, the idea came to him ... This was the creative moment" (Arieti 1976, 268).

I have asked a number of informed individuals—historians, psychologists, and mathematicians—what they remember about Poincaré's essay. Almost invariably the response comes, "he put his foot on the step of the bus ..."—perhaps with some doubt as to whether Poincaré was mounting or dismounting. (He was mounting. Without spoofing, and judging from my own experiences, this may be significant. Starting a trip, or entering a tub, for an intellectually pre-occupied person, is like moving into a pleasantly empty time. Dismounting or detubbing is quite different.) This is an excellent example of the transformation in memory of *telescoping*: a complex event, extended in time is compressed into a point-instant. This results in a double loss, the disappearance both of the inner temporal structure of the event and of its multiple relations with other processes.

The key passage in Poincaré's essay is a two-and-a-half page narrative of mathematical thinking leading up to his first treatise on Fuchsian functions (Poincaré 1952, 52-55). This work did not quite spring from nowhere, but was anticipated, in its point of view and style of thought, in Poincaré's first published paper in 1878. It was not until 1908, almost thirty years later, that Poincaré gave the lecture on mathematical discovery that was included in *Science and Method*, published the same year. Until 1900 Poincaré had been the supreme mathematical analyst. At the Second International Congress of Mathematics in 1900, he proclaimed: "We believe that we no longer appeal to intuition in our reasoning ... We may say today that absolute rigour has been attained" (Bell 1937, 295). But in the following years he moved rapidly in an intuitionist direction. In this he was not alone. There were other similar stirrings. But Poincaré was certainly a princely forerunner of the intuitionist school of mathematical thought. Moreover, in the years just preceding his *Mathematical Discovery* essay, there had been a series of questionnaires to mathematicians, and monographs on the psychology of mathematical thought, generally stressing the role of dream-work and intuition. But none of these reports came from mathematicians of Poincaré's calibre, so his contribution was an important addition (Hadamard 1945).

*Science and Method* is one long argument in praise of both psychological and mathematical intuition: "... what the true scientist alone can see is the link that unites several facts which have a deep but hidden analogy. The anecdote of Newton's apple is probably not true, but it is symbolical, so we will treat it as if it were true" (Poincaré 1952, 27-28). In a critique of bare analytical logic, aimed especially at Russell, Peano, and Hilbert, he concludes: "Logic therefore remains barren, unless it is fertilized by intuition" (p. 193). In an impersonal format, he describes a possible relation between stepwise calculation and penetrating intuition:

> ... when a somewhat lengthy calculation has conducted us to some simple and striking result, we are not satisfied until we have shown that we might have foreseen, if not the whole result, at least its most characteristic features ... The reason is that, in analogous cases, the lengthy calculation might not be able to be used again, while this is not true of the reasoning, often semi-intuitive, which might have enabled us to foresee the result. This reasoning being short we can see all the parts at single glance, so that we perceive immediately what must be changed to adapt it to ... problems of a similar nature (Poincaré 1952, 31-32).

In this discussion he proposes a sequence of processes, a sort of model of mathematical discovery. Arduous work leading to a sound conclusion leads to naming the result leads to compression of thought leads to further economies leads to intuitive grasp. A similar flow is described, or perhaps proposed, in a later chapter. In building an arch, when the edifice has been constructed stone by stone, the scaffold must be removed. Only then can the form of the whole be seen. "What good is it to admire the mason's work in the edifices erected by great architects if we cannot understand the general plan of the master? Now pure logic cannot give us this view of the whole; it is to intuition we must look for it" (p. 126). Although these remarks are framed in a general and impersonal way, it seems reasonable to suppose that they are autobiographical, in that they allude to Poincaré's own experience as a mathematician.

Let us turn now to Poincaré's two-and-a-half page autobiographical fragment (p. 52-55). Following Poincaré's own advice to the reader, I will not pretend that I understand any of the mathematics. Nevertheless, there is much to be gained from a close reading of the recollection. The event as a whole stretches over an indefinite period of time, evidently several months. It can be divided into seven episodes.

(1) *Caen*. For a fortnight he has been deliberately working on a mathematical problem, to prove the non-existence of the class of functions he later called "Fuchsian." A sleepless night, occasioned by too much coffee and too much obsession, leads to a first important idea. By morning he has established the contrary of his original intention. Nothing is said of any sudden illumination. But he does speak of ideas "surging" and "jostling one another," and he does distinguish this phase from the next morning when he spent a few hours to "verify" the result. He seems to be describing a two-phase sequence of intuitive, combinatorial work of discovery followed by some more rigorous process of proof. (Although he speaks of the surging ideas sometimes forming a "stable combination," this does not seem to mean the sudden emergence of solution. In later episodes, when he wants to be explicit about something happening suddenly, he makes himself quite clear. Judging from the whole of Poincaré's essay, these stable combinations seem to surge up from what he calls the "subliminal ego" and are interesting and plausible enough to be presented to consciousness. While many potential ideas are thus excluded, many such plausible combinations arise, only to be discarded.)

(2) *Caen*. At an unspecified time, but apparently soon after the first episode, Poincaré formed a new intention, to represent the functions he had just found in a new way. Quite consciously and deliberately, he adopted the strategy of reasoning backward: "I asked myself what must be the properties of these series, if they existed, and I succeeded without difficulty in forming the series that I have called Theta-Fuchsian."

(3) *Coutances*. A geological conference, ninety kilometres from Caen, where he was living. Here, with no forewarning, he had his celebrated foot-on-the-step-of-the-bus illumination, a perception or recognition of the identity of two mathematical transformations. He waited until his return to Caen to verify his "finding."

(4) *Caen and seaside*. He had begun work on a seemingly unrelated mathematical project, part of a different enterprise. Making no progress, he went away for a few days. "One day, as I was walking on the cliff, the idea came to me, again with the same characteristics of conciseness, suddenness and immediate certainty ..." Again he had perceived an identity, previously unnoticed, between two mathematical transformations.

(5) *Caen*. Returning to his home and teaching post, he deduced the consequences of his new finding and set about systematizing and generalizing it. He succeeded easily, with one notable exception. Struggling with this obstacle did help him "better understand the difficulty, which was already something. All this work was perfectly conscious."

(6) *Mont-Valérien*. Military service, near Paris, about 200 km from Caen. "... my mind was preoccupied with very different matters. One day, as I was crossing the street, the solution of the difficulty which had brought me to a standstill came to me all at once. I did not try to fathom it immediately, and it was only after my service was finished that I returned to the question. I had all the elements and had only to assemble and arrange them." Here I have re-grouped Poincaré's narrative a little, so that this episode spans one period in Mont-Valérien and one in Caen. This way of dividing the whole event brings out the point that the solution that came to him all at once was clearly not a finished product, but something that needed further fathoming and re-organizing.

(7) *Caen*. Now having all the elements of his definitive treatise, he composed it "at a sitting and without any difficulty."

Of these seven episodes, then, three include sudden illuminations—on the bus, on the cliff, and in the street. Another is described as freighted with intuitive thought. The remaining three are characterized as conscious and deliberate work. For Poincaré, one of the hallmarks of his sudden illuminations is the suspension of intentional work on the problem, although this is not necessarily the case for other individuals.

Thus, Poincaré gives a first-order description, not of one great insight but of a continuously working, evolving system of thought that produces important insights from time to time. As I read him he is probably thinking about mathematics almost all the time. It should be remembered that during the period described he was not only working on the problem of automorphic functions, but on a wide range of mathematical subjects. For Poincaré, mathematics was a language he thought in. "To Poincaré ... analysis came as naturally as thinking" (Bell 1937, 597). For him, making plausible or "polite" mathematical statements was probably similar to a non-mathematician spontaneously uttering well-formed sentences in a language he knows well. No more mysterious than that—and no less!

Einstein said somewhere, "If atoms could talk I would surely listen." But there are many difficulties to be faced in listening to people describing their thinking (Ericsson and Simon 1980). We are not required to take such descriptions at face value. Even those aspects of cognitive processes that are potentially available for subjective reports will inevitably be selected and organized in ways depending on the state and direction of movement of theory at the time the report is made. These difficulties arise from the dual role of the person reporting as actor and observer. In both roles he is guided by theories, but the theories in question may or may not form a coherent whole. Poincaré was functioning both as a mathematician and as a psychologist when he wrote his essay on mathematical discovery. "Intuition" does not have quite the same meaning in these two universes of discourse. As a recent convert to intuitionism, Poincaré strove to apply his point of view to both domains. We cannot read his recollections as unprocessed memories, for they have gone through this complex and uncertain system of filters. To these complexities must be added the more mundane facts of forgetting and telescoping that enter into all recollections. In spite of these reservations, Poincaré's account and others like it are surely a great mine of knowledge about creative thinking. We should listen.

There are at least three levels in Poincaré's description: mathematics itself, his own thought processes about mathematics, and his more general reflections on the psychology of thinking. All of these must be considered seriously. If a thinker says "my thoughts came at random," we do not have to believe there was a Monte Carlo machine in his head. Indeed, we have good enough experimental evidence that it is impossible to have random thoughts. Nevertheless, if the process feels haphazard to the thinker, that means something. The feeling may stem from the spontaneity of the process; or it may be difficult to perceive a conventionally acceptable ordering of the ideas; or the ideas that arise may be irrelevant to the line of thought that ultimately prevailed. Not only must we take such first-order descriptions as a basis for our reconstructive efforts, we must look at what may be called second-order descriptions. If the thinker says something like "invention is choice," his remark is cast in a general form with which we may or may not agree. Nevertheless, we may want to consider the remark as a kind of subjective report by that person that he or she had such experience of choosing. Actually, Poincaré, who made that remark, probably meant something else. A somewhat fuller version reads, "Discovery is discernment, selection" (Poincaré 1952, 51). He viewed the subliminal ego as the stage at which much of the discernment, and certainly the more refined and subtler judgments, take place.

Poincaré's theory of creative mathematical thinking proposes a complex relation between conscious and unconscious mental work. First, a period of deliberate, conscious work selects certain ideas as potentially relevant to the solution sought. Second, a period of deliberate combinatorial activity, trying to find a "satisfactory arrangement" of these ideas or elements. Third, when this fails, "a period of apparent repose, but of unconscious work" begins, during which the spontaneous illuminations under consideration may occur.

Poincaré was very careful to emphasize the ways in which the creative process is regulated by the thinker's conscious and enduring purposes. On the one hand, he compares the elementary ideas of a mathematician's thought process to molecules in a gas (or equally, to Epicurus' "hooked atoms"), whose collisions produce new combinations. On the other hand he says of these elements, "Now our will did not select them at random but in pursuit of a perfectly definite aim. Those it has liberated are not, therefore, chance atoms; they are those from which we may reasonably expect the desired solution" (p. 61). And again: "... the only combinations that have any chance of being formed are those in which at least one of the elements is one of the atoms deliberately selected by our will" (p. 61). Finally, whatever is produced by these unconscious processes must be developed in a second period of conscious work. "It never happens that unconscious work supplies *ready-made* the result of a lengthy calculation in which we have only to apply fixed rules ... All that we can hope from those inspirations ... is to obtain points of departure for such calculations." The latter "demand discipline, attention, will, and consequently consciousness" (p. 62-63).

Thus Poincaré's argument, after his intuitionist conversion, was a carefully balanced one. The conscious purposeful person sets up a mental situation with a number of constraints, all promoting the likelihood that thinking will go in a certain direction. Within these constraints the "subliminal ego" operates with a certain "absence of discipline" which permits the "unexpected couplings" that must then be exploited in a disciplined way.

In the way it has been often cited, Poincaré's account of his insight makes mathematical creativity resemble what is loosely termed "autistic thinking." But this is based on a very hasty and partial reading. Actually his reflections on the creative process resemble my approach, stressing the idea of creativity as purposeful work with, of course, much spontaneity.

But one vital point must be added. Poincaré as psychologist is considering what I would call a single episode. Such episodes are very far from constituting the whole creative process. Poincaré's own brief narrative, discussed above, shows admirably how indispensable it is for the person to marshall his efforts in an extended series of such episodes composing an intellectual growth process on another time-scale. For this growth to display any sense and order, the intentional episodes must be embedded in a still larger framework of purpose, regulated by an overarching point of view.

## CONCLUSION

The more one looks at a case, the more one sees that a seemingly sudden inspiration exhibits a complex history of purposeful growth and a dense inner structure. This view is supported in a very detailed study of a modern biologist by June Goodfield (1980). There is almost certainly a great deal of loss and re-organizing in memory, some of it immediate and some of it developing over a period of years. Richard Westfall makes the point than Newton's *annus mirabilis* was not quite so definitively miraculous as Newton's recollection of it. "There is evidence that Newton did indeed begin work near the time of the *annus mirabilis* in the three areas of mathematics, optics, and mechanics and gravitation, though his achievement was not as complete as he later recalled" (Westfall 1980b).

A telling fact is the way in which the term episode inevitably changes its scope of reference as one recalls an intellectual process. In any problem-solving process there are episodes within episodes, and there are temporally overlapping episodes: one sequence often begins before another is ended. Moreover, what was once experienced as a series of distinct episodes may later be remembered as a single event. The regrouping of memories is a fact familiar to cognitive psychologists.

Starting with haphazardly arranged materials (e.g., nonsense lists)— as psychologists often do—the direction of change is, in the main, toward improved organization and simplification. To this we may add the point that in repeating a problem-solving process the solution changes structurally in subtle ways. Distinct steps are re-organized into new blocks; previously necessary steps become superfluous; and details are inserted (Gruber 1976b). Scientists do in fact usually repeat solution processes in their writing, in their teaching and in the course of perfecting, verifying, and extending their enquiries.

This process of constant reorganization of ideas, both while working on them and in memory, may help to explain some aspects of the *Eureka* phenomenon. The thinking person goes over the same ground many times. He focuses now on this particular aspect, now on that, now on the problem as a whole. He looks at it from varying points of view—his own, his arch-enemy's, others'. He diagrams it, verbalizes it, formulates equations, constructs visual images of the whole problem or of troublesome parts or of what is clearly known. But he does not keep a detailed record of all this mental work, indeed could not. The fact that this work involves various changes in scale and perspective makes it possible for something to be at once old and new. Before ever going there, I had seen small pictures of the Grand Canyon of the Colorado River. I first saw the real thing by moonlight—eerie and terrifying—and then a few hours later in a glorious dawn. None of these experiences quite prepared me for the others, yet they were all "partially isomorphic."[1]

To improve our understanding of the *Eureka* phenomenon the direction in which to work may be to study the relationships among different experiences of the same thing: the same idea worked through by different means and in different modalities; the same idea felt and then thought, and then felt again—but in a new way for now the feeling contains a new thought. Deep understanding of a domain of knowledge requires knowing it in various ways. This multiplicity of perspectives grows slowly through hard work and sets the stage for the re-cognition we experience as a new insight.

1. Piaget's term. H. E. Gardner (1980b) has made a similar suggestion to account for Mozart's description of himself as experiencing a complex musical piece all at once.

# The Cooperative Synthesis of Disparate Points of View

## Introduction

### *The Perplexities of Truth*

In Plato's *parable of the cave* the prisoners are chained to a single station point and see nothing but shadows on a wall. They have no way of distancing or decentering themselves from this one limited view of the world. It is all they know. Limited and distorted as it may be, that is their "reality." Plato's point is that this is the normal situation of ordinary mortals.

The classic studies of conformity by Sherif (1936) and by Asch (1952, 1956, 1961) stemmed from rather different perspectives about the truth-value of beliefs. Sherif thought that the function of social norms can be appropriately studied with highly ambiguous stimulus situation, notably the autokinetic effect, and that this ambiguity corresponds well to real-world conditions. In response to this work, Asch was concerned with the suggested image of human nature as passively yielding to the group; he believed that when confronted with unambiguous stimuli, notably easily discriminated lines, observers would see things accurately, would resist conformity pressures, and would report faithfully what they saw: People can be vigorously truthful. I believe that Asch was taken by surprise at the discovery that, under such unequivocal conditions, there was any yielding at all.

In spite of important differences in their methods and in their world views as expressed in their experiments, Sherif's work on the formation of social norms and Asch's work on group pressures have certain points in common. First, the subjects are all looking at the scene to be judged in essentially the same way and front the same point of view. Thus, a difference in the report of what is seen must mean a disagreement. Second, there is no opportunity for dialogue among the observers; each one is limited to looking at the stimulus, listening to the others' judgments, and making his or her own report. Third, the subjects are limited to looking and listening; they have no opportunity for a more active exploratory or manipulative approach to the material to be apprehended. Fourth, the situation invites only judgment on a single variable, not the construction of a complex idea or object. Under such conditions, intersubjective differences become disagreements that can only be resolved by yielding, domination, and compromise—all of which occur.

*Synthesis of disparate points of view*. The approaches outlined above are, within limits, impeccable. Each reflects some experimental findings and corresponds to some of our nonexperimental knowledge of the world. But they do not give us much

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guidance as to how people, sometimes at least, struggle toward the truth. In this regard there is at least one type of situation that is not covered by previous research, situations requiring the synthesis of different points of view.

It is possible to imagine conditions in which different observers have different information about the same reality but have no need to disagree with each other. Moreover, if they are fortunate enough to discover each other, they may be able to transcend their individual limitations and together arrive at a deeper grasp of the reality in question than would be possible for either one alone. We have embodied this type of situation in the microcosm of a "shadow box" (See Figure 1, page 221). This is an arrangement in which an object concealed in a box casts two different shadows on two screens at right angles to each other. The subjects' task is to combine or synthesize these shadows in order to work out the shape of the hidden object. In what follows, I will refer mainly to situations with two points of view and two participants, although other arrangements are obviously possible.

When we refer to the different points of view as *disparate* it is to emphasize the analogy of the shadow box with binocular vision. In both cases two different images give rise to a single psychological object, in one case through direct perception, in the other through problem solving and creative synthesis. Were it not for the synthesis, the multiple images might lead to confusion rather than to improved knowledge of the world.

The cooperative synthesis of disparate points of view in the shadow-box situation is not a simple matter: A prior assumption must be made that the participants' observations correspond to the same entity. Each participant must convey his or her knowledge to the other clearly and correctly; this may require the invention of a scheme for representing the information in question. When difficulties of communication arise, the problem of trusting the other person must he dealt with. Often, too, the subject must overcome a common tendency to ignore or underemphasize the other person's contribution, and to center attention on one's own point of view.

While these problems are being solved, the actual work of synthesis goes forward: How exactly can we put this configuration together with that one to form a coherent whole? Once again there are interacting problems of cognition and communication to be resolved.

Up to this point, I have presented the problem of synthesis in a social guise: the *cooperative* synthesis of different points of view. But clearly, there will be some situations where, in principle, one person can move back and forth between different points of view. Experimentally, the two point of view situation permits us to compare the performance of an individual with that of a pair. A priori, one can think of good arguments for the superiority of either arrangement. On the one hand, the individual perceptual apparatus is admirably organized for synthesizing disparate inputs: binocular vision, the kinetic depth effect, and all sorts of inter-modal phenomena testify to this capability. On the other hand, although the literature on group problem solving is ambiguous about this, there are at least some situations in which two heads are better than one.

From a practical point of view, the question of one head or two may not always be germane. There are, after all, situations in which shuttling back and forth between station points is not feasible, so there must be an observer at each point. For example, this may be the case with two astronomers viewing the heavens from different points on the earth. And if we generalize the idea to negotiating situations, the number of heads will be determined by socio-political realities. The processes involved in the cooperative synthesis of points of view are therefore interesting in their own right.

*Reichenbach's "cubical world."* In certain respects our shadow box resembles Reichenbach's (1938) philosophical examination of a hypothetical "cubical world." In this world, the inhabitants are enclosed within a very large hollow cube, made with translucent walls and ceiling. Outside, birds fly around and cast shadows on the walls and ceiling, but the inhabitants know nothing of birds. They see only dark spots moving haphazardly. Here Reichenbach introduces a complication. There is a very large mirror, so placed that at some moments a single bird may cast two shadows, one on the ceiling and another on the wall opposite the mirror. But the inhabitants are not aware of these coincidences or of their significance. One day, among the inhabitants there appears a "Copernicus"—a genius who notices the coincidences, reflects upon their meaning, and deduces the existence of the world outside and of the creatures casting the shadows.

Reichenbach's cubical world is interesting to us both for its similarities and dissimilarities to the shadow-box world. Evidently, the mirror produces the equivalent of two points of view, but this fact must be discovered; in our shadow-box work, for the most part, we have shown the subjects directly how the two viewing points make two different shadows visible. Reichenbach's "Copernicus" solves only what we have come to call the *correspondence* problem: He recognizes that a given pair of shadows, projected onto different surfaces, are produced by the same object. But Reichenbach does not raise the construction problem—how to put the specific shapes of the shadows together to form a definite three-dimensional object; this constructive synthesis of points of view is the heart of our shadow-box experiments. Finally, Copernicus makes his discovery alone. In fact he could do it standing still and silent, since both projections are visible from one point; in the shadow-box world, the subject working alone must move from one station point to another, or if two subjects are working together they must communicate—and effectively. Dialogue thus becomes an integral part of the process of synthesis.

*Perspective-taking and the three-mountain problem.* In the research approaches already discussed the thrust has been reality-oriented. The subject is asked, in effect, "what is out there?" In contrast, in the three-mountain problem studied by Piaget and Inhelder (1956), what is out there is completely visible. The subject sees the scene, an array of objects on a table, from one vantage point. The question put is not "What is there?" but "What would another person see?", looking at the same scene from a different vantage point.

In this well known and often repeated experiment, Piaget and Inhelder found that young children were unable to "decenter" correctly from their own point of view. Piaget and Inhelder labeled this characteristic "egocentrism."

There is little dispute over the difficulty of the three-mountain problem for children. But there are important differences in interpretation of the results. By now there seems to be widespread agreement that in some sense very young children sometimes behave in ways implying a grasp of the other person's point of view. For example, the child of sixteen months looks appropriately where others point, and points at objects correctly, coordinating the act with vocalizations that appropriately attract another's attention (Leung and Rheingold 1981).

At the other extreme, there is little doubt that in some situations mature and sophisticated adults fail to see the other person's point of view. Probably whenever the task is difficult enough, or emotion intense enough, one common form of error is the lapse into egocentrism.

With regard to the three-mountain problem itself, it has been argued, with some experimental support (Liben 1978; Liben and Belnap 1981), that the child's most typical error is not to predict that the other will see what it sees, but rather to predict that the other will see the view that best represents what the child knows about the scene. It seems to me that these findings could be described as another form of egocentrism: confusing one's immediate experience with what one knows to be the case.

In spite of their evident differences, the past research discussed earlier (Sherif, Asch, Piaget, etc.), have one key point in common: the emphasis is on judgment. The subject engages in little or no active exploration, discussion, and construction. (To be fair, this is not true of Piaget's other work. Moreover, Doise and Mugny (1979) studied children cooperating in working on the three-mountain problem; their focus, however, was not on the process of synthesis of different points of view, but on the effects of cooperation on the later cognitive level of the child working alone.)

Peculiarly, in a number of studies of cooperation (e.g., Doise and Mugny 1979, 1981; Emler and Valiant 1982) the investigators' emphasis has been on the growth-potentiating value of conflicts engendered within the cooperative situation, rather than on more obviously positive processes, such as helping behavior.

There is a need, therefore, for some study of the cooperative synthesis of different points of view in tasks requiring active discussions, exploration of possibilities, and construction. It seems to me that such studies are entirely in the spirit of Asch's own thinking about these matters.

## STUDIES OF THE SYNTHESIS OF DISPARATE POINTS OF VIEW

Our main aim was to study the cooperative synthesis of different points of view, but in order to pursue this aim we also studied individuals working alone. This had unexpected results.

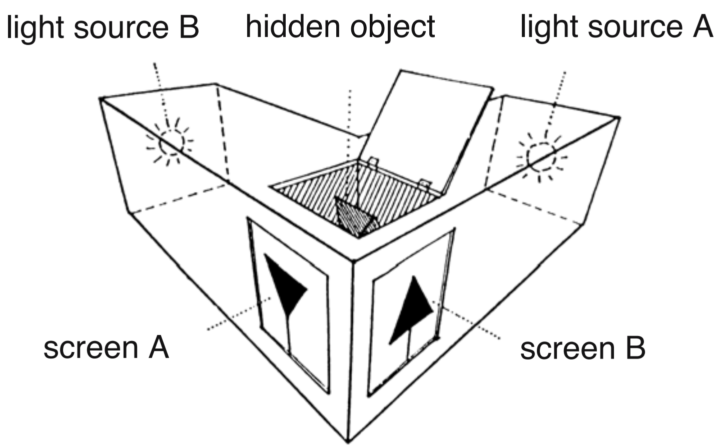


*Figure 1.* The shadow box. The synthesis of different points of view. The task is to use the two shadows to work out the shape of the hidden object.

In the experiments summarized here we followed a common pattern. The subject or subjects were first familiarized with or reminded about the general nature of shadows. Then they were introduced to the shadow box: they looked inside, saw the two light sources and the two screens, and saw how an object could be mounted on a vertical stalk in such a position that it cast a shadow on each screen. From each of the two viewing points only one shadow was visible.

In conditions with pairs of subjects, they were asked to communicate with each other about what they saw, and to try to work together to come to an agreement as to what shape of object inside the box would account for the two shadows. They were given paper, pens and scissors, modeling clay, and where appropriate, Lego blocks with which to construct an object like the concealed one. In conditions with a single subject working alone, he or she was given the same materials and asked to go back and forth between the two station points as often as desired in order to solve the problem. There were no time pressures put on the subjects.

*Experiment 1: Interaction of Social and Cognitive Factors*

In this study we compared subjects working in pairs with subjects working alone. There were 12 single subjects and 12 same-sex pairs of both sexes in each of 3 age groups; thus 36 children (7-9 years), 36 adolescents (14-16 years), and 36 adults (20-

53 years). Each single or pair worked on two Lego objects and two geometrical objects (Figure 2.). The order of presentation of objects was counterbalanced. There were always two experimenters present and all sessions were videotaped.

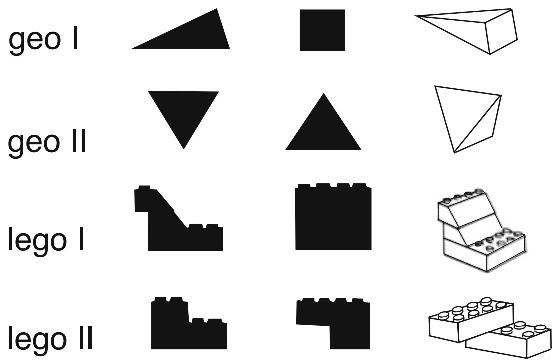


*Figure 2.* Objects and shadows in Experiment 1. Different kinds of material

The subjects almost invariably found the task challenging and interesting, and willingly worked on it for as long as an hour. The task can be very difficult, as shown by the length of time taken; also, as shown in Figure 3., among the children the majority failed to solve any of the objects, and among the adolescents and adults there were still some who failed completely.

As shown in Figure 4., the subjects used three main strategies: recognition, addition, and transformation (or multiplication). Recognition of a familiar object can play a role even with the seemingly abstract shapes, since, for example, a square shadow and triangular shadow can be additively composed into a "house" (with square as the building and the triangle as the roof). Or the triangular shadow can (presumably with a little help from the other shadow) evoke the response, "piece of cheese." The additional strategy consists in simply juxtaposing two planes, which can be done either correctly or incorrectly. Mixed strategies occur, such as combinations of recognition and juxtaposition.

Among the children, use of the recognition strategy was quite frequent (often incorrectly). Among adolescents and adults, the work of synthesis usually led to the understanding that the shape of the shadow does not necessarily correspond to any face of the object; and similarly that, even though the planes of the shadows were ver-

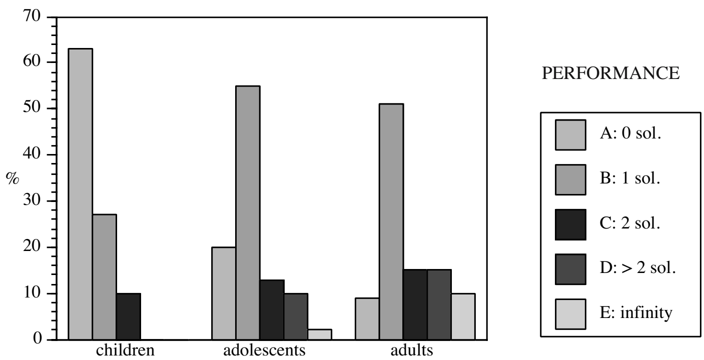


*Figure 3.* Developmental differences in synthesis of points of view. Percent of subjects in each age group exhibiting different performance levels in solving shadow-box problems.

tical, the planes of the surfaces of the object might or might not be so. Among the adults, most subjects began the process of construction and transformation immediately.

We speak of "transformation" or "multiplication" because taking both shadows into account at once can lead the subject to move from identifying the shadow with a face of the sought-for object to some other way of viewing the whole object. For example, in "Lego 2" (Figure 2.), a correct solution requires the subject(s) to grasp the way in which the two pieces are offset from each other, so that a region which appears on the screen as "up front" in the shadow may correspond to a rearward part of the object. The difficulty of recognizing this point led to characteristic errors among the children, and to quite a struggle for the adolescents and even for some adults.

The task requires at least a double and, for what we came to consider optimal performance, a triple decentration on the subject's part. First, the subject must avoid basing his efforts on a single shadow; this can happen even to a subject working alone, much as the solitary chess player playing both sides of the board has difficulty in remaining decentered. Second, the subject must separate the plane of the shadow from the various possible planes of the object. Third, for an optimal performance, recognizing the multiplicity of possible solutions, the subject must distance himself or herself from the first solution discovered. In the case of pairs, this may mean acknowledging that the other person's solution is good, too. Figure 5. shows some examples of possible solutions for two of the objects used in the experiment.

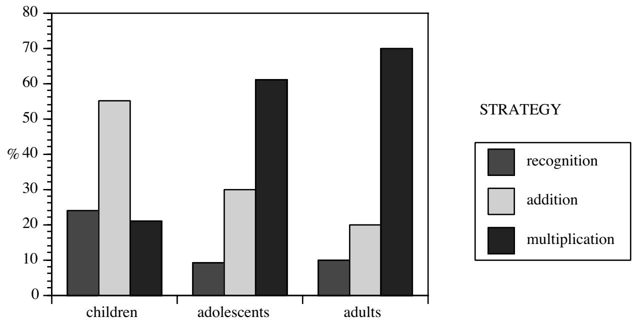


*Figure 4.* Use of different strategies in solving shadow-box problems.

For each object, the performances of the singles and pairs were coded into one of five categories: (A) zero correct solutions; (B) one correct solution; (C) two different correct solutions; (D) more than two correct solutions for a given pair of shadows; (E) the concept of an infinite number of possible solutions. This last category was only used for performances where the subjects had already achieved at least one correct solution. In other words, it would not have been used for an "anything goes" reaction to the task.

An analysis of variance (3 ages × 2 kinds of object × 2 social conditions—singles and pairs) was performed on these data. For this analysis the scores for the two objects of a given type were combined. The main effects of age and kind of object were highly significant. The effect of social condition was insignificant. The main difference between children and the other two groups was that most of the children failed to produce any correct solutions. The main difference between the adolescents and the adults was in the greater number of adults who found two or more correct solutions for a given pair of shadows and who recognized the possibility of an infinite number of solutions (See Figure 3.).

The pattern of responses was different for the Lego objects and the geometrical objects. The Lego objects were more difficult both in the sense that there were more total failures and in the sense that there were fewer instances of multiple solutions (categories D, and E). These results permit only a cautious conclusion, that the particular nature of the object and the shadows it generates have a considerable effect on performance.

Based on our exploratory work we undertook this study with two questions about the difference between singles and pairs: First, would there be an important difference in success between the two conditions? Second, would the pairs produce a larger number of multiple solutions (categories I and II)? Both questions must be answered in the negative. It may be that the processes involved are different, but happen to lead to similar results under the particular conditions of this experiment.

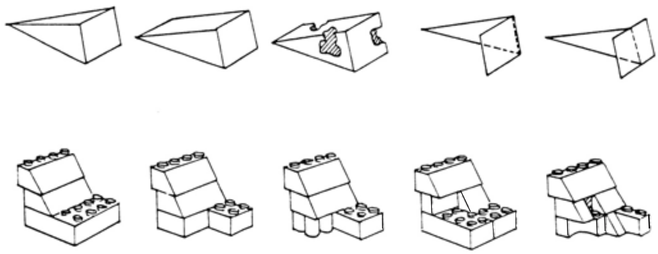

*Figure 5.* Alternative solutions compatible with shadows presented.

On the other hand, it is also true, in spite of the evident differences in behavior between singles and pairs, that there are moments when, within a pair, an individual is in effect working alone. To support the claim that cooperative work is effective, there is no need to insist that working alone is ineffective. We need a more differentiated view of the process of cooperation, taking account of the ebb and flow of interaction. It should be added that working alone is not entirely an asocial process.

Initially, the basic shadow-box situation, even with a single subject, was understood as a simulation of the cooperative synthesis of points of view. But we soon came to think that the pair condition would yield better results, because two heads are better than one. To our surprise, in a number of different experiments there was little difference in problem-solving success between the single and pair conditions. In only one respect was the pair condition clearly superior to the single: the frequency of multiple solutions. And this superiority was more pronounced in adult pairs than in adolescent pairs.

*Experiment 2: Comparison of Cooperative and Individualistic Orientations*

Reflecting on our work thus far we came to realize that the distinction between working alone and in pairs is too crude. Within pairs there may be all sorts of relationships. Our next goal was to examine this question by comparing the effects of different social orientations within pairs on the synthesis of points of view. To this end, we used three different kinds of instruction to the pairs. The *cooperative* instruction encouraged the pair to work together throughout the whole experiment, indicating that their performance would be evaluated as a pair compares with other pairs, not as individuals. The *individualist* instruction asked the subjects to exchange information—as to their respective shadows and then to work alone in solving the problem, indicating that their performance would be evaluated as individuals. The *neutral* instruction did not specify any mode of working together and did not mention evaluation.

The subjects were 24 pairs of adolescents (14-16 years old) and 24 pairs of adults (23-58 years old). All pairs were same-sex, and the subjects knew each other as friends, classmates, and colleagues. Within both age groups the number of males and females were equal. In the results, there were no consistent or striking differences between the sexes, so that variable is ignored in what follows.

Each pair was given a single problem, a tetrahedron fixed on an edge in such a position that each subject saw a triangular shadow, one with apex up, the other with apex down (see Figure 2.). We chose this rather difficult task in order to avoid a ceiling effect and to keep the pairs working long enough for the observations we hoped to make. As before, all performances were videotaped, and there were two experimenters present at every session.

*Table 1.* : Developmental differences in social behaviour. Number of subjects in each of three behavioral tendencies: cooperative, independent, or competitive.

| *Adults* | | | | |
|---|---|---|---|---|
| | | | *Social Behaviour* | |
| | | cooperative | independent | competitive |
| | cooperative | 13 | 2 | 1 |
| *Instructions* | ind | 7 | 8 | 1 |
| | comp | 13 | 3 | 0 |

| *Adolescents* | | | | |
|---|---|---|---|---|
| | | | *Social Behaviour* | |
| | | cooperative | independent | competitive |
| | cooperative | 8 | 6 | 2 |
| *Instructions* | ind | 2 | 14 | 0 |
| | comp | 10 | 5 | 1 |

The resulting patterns of social behavior could be classified as individualist, cooperative, or competitive. We categorized the individual performances rather than the pairs, since the members of a pair did not necessarily act the same way. As shown in Table 1., subjects by no means followed the instructions we gave them. Among the adults the predominant behavior was cooperative, both in the groups given cooperative and neutral instructions; even in the group given individualist instructions, almost half of the subjects were cooperative. It seemed almost as though the shadow-box situation, presenting two perspectives bearing on a single object, naturally evoked cooperation as the appropriate response mode.

Nevertheless, among the adolescents given the individualistic instruction, the predominant response mode was individualistic, with divided results in the other two groups. In both age groups and all conditions, competitive relationships were quite rare.

We arrived at a composite score for each subject, based on the number of correct solutions produced during the problem-solving phase of the experiment and on responses during a post-experimental interview to questions about the possibility of alternative solutions. The highest score, 6, would be achieved by a subject who produced multiple solutions during the problem-solving phase and who could, during the interview, elaborate the idea of an infinite number of possible objects producing the same projections.

For an age × social behavior × total performance analysis of variance, we combined the individualist and competitive subjects (classified according to their actual behavior, not the instructions they had received). Adults performed significantly better than adolescents ($p < 0.002$). But neither the effect of social behavior nor the interaction of social behavior and age was significant. The difference between age groups is due to differences both during the problem solving phase and the interview. Failure to construct at least one correct solution was more frequent in adolescents, and adults were clearly more sophisticated in handling the idea of multiple solutions. The idea of an infinite number of solutions occurred only in adults (8/48 subjects).

Most of the best adult pairs were ones in which both members were cooperative. Moreover, in six of the eight best pairs, the partners had *different* problem-solving strategies, one working mainly by addition of planes and the other by constructing volumes. In exchanging information the adults were more precise and detailed than adolescents, giving information not only about shape but also about orientation, size, and position on the screen. In solving the problems, the adults give equal weight to both shadows, whereas the adolescents tend to focus on their own viewpoint. Adults were more attentive to their partner's suggestions, and they profited from their differences by improving the quality of their solutions and of their comprehension of the task. The adolescents were less interested in the other's ideas. They were also more concerned about whose solution is correct, as if only one were possible.

## DISCUSSION AND CONCLUSION

*Cooperative synthesis of different points of view.* With the shadow-box task we created a situation in which syntheses of disparate points of view could be accomplished either by an individual with full access to both perspectives or by a pair of communicating subjects. The most important result is that such syntheses are possible and that they are, for the most part, difficult. We were not able to demonstrate any conclusive superiority of cooperating pairs over individuals with full access. On the other hand, we were able to create a situation in which cooperation was necessary for successful task resolution. Finally, in this regard, full cooperation with adequate attention to and respect for the other was distinctly more characteristic of adults than of adolescents, and led to more sophisticated performances.

In a sense, comparing individual and cooperative performance is asking the wrong question. In order to make such comparisons it is necessary to study situations where the choice of either kind of behavior is within reason. But if we are interested in cooperation, it should be studied primarily in situations where it is essential, and the question should be "how does it work?"

The process of synthesis of disparate points of view is extremely complex. In the sense that it requires the construction of something new, it has some of the properties of creative work (Gruber 1989c; Wallace and Gruber 1989). A kindred point was recognized by Crutchfield (1964) in his study of conformity and creativity.

*Self and other*. In some respects, of course, the synthesis of disparate points of view appears early in life, with binocular vision. But there is a long developmental road from such perceptual beginnings to successful performance in the shadow-box task. Few children between the ages of seven to nine could do it. We have additional evidence suggesting that the cognitive level reflected in successful performance in the three-mountain problem is a necessary but not sufficient prerequisite for success in the shadow-box task (Giacomini-Biraud 1988). In other words, the ability to understand correctly what will be seen from another perspective is a prerequisite to being able to "turn around" and use two perspectives to construct an unknown object.

It would seem reasonable to suppose a distinct interaction between self-awareness and other-awareness. This idea is dramatically illustrated by the account of a deaf child who could lipread and speak, but who had no idea that he was deaf (Degand 1911). At the age of eight, he noticed with astonishment that his teacher could understand him without her seeing his lips. From then on he was attentive to other children, interested in classifying them according to their perspectives on the world: Could they understand without seeing (i.e. hear) or not? Although the interaction between self-concept and other-awareness may seem reasonable, there is an almost complete separation of the psychological literatures dealing with these topics (Ford 1979; Baumeister 1987).

*Appearance and reality*. The synthesis of different points of view must depend on some grasp of the distinction between appearance and reality. If the subject does not posit a unifying object or real world, then each scene is just a scene, more or less like other moments of experience. In order to interact with each other, both cooperating subjects must assume the distinction between appearance and reality, and further, they must both assume that their different perspectives bear on the same reality. In other words, the subjects must have at least a tacit agreement as to the solution of the correspondence problem.

Although there has not been much research with adult subjects on the relation between appearance and reality (but see Brunswik 1956; Gruber and Dinnerstein 1965), there has been a recent spate of research on the child's growing comprehension of the distinction between them (Flavell 1986). Flavell, Flavell, and Green (1987) have carried the argument further and attempted to demonstrate that there is a "pretend-reality" distinction that emerges in three-four year olds, or about a year before the appearance-reality distinction. For an example, the child of three, playing with a wooden block and pretending it is a car, knows perfectly well that it is both a real block and a pretend car. Flavell et al. argue that the pretend-reality distinction not only precedes but leads to the appearance-reality distinction: What the child first constructs he later confronts.

Although it is tempting and plausible to elaborate such neat sequential taxonomies, I doubt if they will stand up very long. Peek-a-boo and other hiding games emerge in babies very early. They involve some grasp of the point of view of the other, some knowledge of pretend appearance-reality distinctions, and even some cooperative effort. It is equally plausible to conceive of approaches to reality as developing a spiral of increasing complexity, with each of many schemata becoming more and more powerful.

*The correspondence problem*. In the experiments reported here we solved the correspondence problem for the subjects. That is, we showed them in advance exactly how the two shadows correspond to the same object. But as we have seen, in Reichenbach's cubical world, it takes a "Copernicus" to solve the correspondence problem. We have now invented a situation in which our subjects can confront that issue. There are two objects in the shadow box, producing four shadows, two on each screen. The subjects must first work out how to pair off the shadows—which goes with which?—*(the correspondence problem)* before they can arrive at a cogent proposal as to the shapes of the objects. At the same time, preliminary glimmerings about possible shapes affect the decision as to how to pair the shadows.

The discovery that adults are more keenly aware than adolescents of multiple solutions is one of the most interesting findings of our work thus far. We thought that the four-shadow situation would make this kind of solution more salient. To our surprise, preliminary findings suggest that the opposite is the case. Subjects who exert themselves to solve the correspondence problem both ways are then satisfied with one solution of the object shape problem for each correspondence, and do not go on to discover that there are alternative solutions for a given choice of correspondences.

*The Copernicus question*. Does it really take a Copernicus to perform excellently on the shadow-box problems? Our initial expectation was quite the contrary. Part of the motivation for the construction of the shadow box was the idea that it is the point of view that counts: Endow subjects with access to multiple perspectives and they will be able to transcend their individual limitations. Our research has shown that this idea is only partially substantiated. There are both wide individual differences and strong developmental trends in the synthesis of disparate points of view. Apart from our experimental subjects we have tested a few individuals, including a distinguished mathematician and a physicist, who seem to function at a much higher level.

We undertook this work as part of an approach that recognizes the social construction of knowledge without falling into the morass of extreme relativism: Exploiting multiple perspectives is one form of acquiring an enlarged vision. We can now see that such an approach does not require everyone to make equally good use of such possibilities. It is enough that those few who see the furthest can successfully communicate what they see to others.

## ACKNOWLEDGEMENTS

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# CHAPTER 4

# MODALITIES

*The Stuff of Experience*

Stream of consciousness is one of the great organizing principles in the field of psychology, and William James, the "father" of psychology, is its patron saint. In spite of wide recognition of stream of consciousness, surprisingly little empirical work has been done to elaborate it. It may well be that the hard-nosed experimentalists wouldn't touch it because it's too soft. Meanwhile the romantics who love stream of consciousness felt that putting it under the empiricist's microscope could kill it.

In the late nineteenth and early twentieth century, mental imagery and other subjective phenomena fell out of favor both for empirical and metaphysical reasons. With the coming of Watsonian behaviorism, imagery and other covert or subjective phenomena were strictly taboo. In the 1930s and 1940s, Gestalt psychology gained in prominence. Considering this school's intense interest in perception, and reliance on it for theoretical models, their scanty productivity in this area is surprising. I cut my eye teeth on Wertheimer's *Productive Thinking* (1945), a book that might well be titled "Problem Solving" but never, for example "Metaphor and Thought." After World War II, symbolic forms other than language came back into fashion as fields of study. It should be mentioned that several psychologists close to the classical Gestalt triumvirate (Wertheimer, Köhler, Koffka) did take up questions of meaning similar to the issue of metaphor—notably Werner, Arnheim and my teacher, Asch.

## ONE OR MANY?

There is no unique stuff out of which our thoughts are made, although psychologists from different camps have repeatedly embraced a cognitive monism, seeing one form—e.g., sub-vocal speech, visual imagery or, most recently, propositional representations—as the basic modality of the mind.

I have been concerned with the plurality of cognitive modalities, experimentally as well as theoretically. Variability and multiplicity has been a theme in my work from early on. In *From Perception to Thought* I emphasize this theme, looking at shifts between different modalities as distinctive to cognition. Such shifts vary "from moment to moment, from perception to imagery, to motor exploration, to the use of linguistic symbols, and so on, in a never-ending stream" (see page 235). I adopted the concept of transformation from my work in perception to explain how we get "from one cognitive moment to another" (see page 236), i.e., to account for the continuity of cognitive life despite its never-ending change.

In early experimental work, I explored the notion that, even in perceptual experiences that seem immediate enough to be considered pure and simple, switches between different modalities occur. For example, subjects of an experiment on the perception of causality imaginatively filled in temporal or spatial gaps between the test events in widely differing ways, but always created the impression of causality (Gruber et al. 1957).

This section addresses the issue of plural cognitive modalities in creative thinking. We explore the mental space in which a scientist moves to accommodate recalcitrant findings or to analyze vague concepts, bringing out hidden relations between ideas. These papers highlight a widely neglected and disparaged dimension of scientific work: the aesthetic one.

And even within one modality, we find others. In Darwin playing or struggling with metaphors, trying to capture different aspects of his central theoretical ideas, two aesthetic moods are expressed which imbue scientific thinking about nature. Piaget—a psychologist with a marked predilection for logical symbols—is shown as a young man writing poems that prefigure one of his main theoretical themes: ascending equilibrium. These four papers delineate some of the often covert connections between scientific and aesthetic creativity.

## ENSEMBLE OF METAPHOR

The main topic of the second and the third paper in this section is metaphor. Metaphor has, of course, long ceased to be considered as a mere figure of speech, a poetic application to one thing of a quality belonging to another. Metaphor is no longer a stranger to the realm of science (actually it never was); it is widely acknowledged that metaphors pervade scientific discourse. But the question whether they properly do so remains controversial. Aiming at a clearly defined if not an operationalized theory language, positivists have tended to deny this; according to them, metaphors might have pedagogical uses or, at best, a heuristic function during early phases of the genesis of a theory. Metaphor is regarded as a kind of scaffolding to be discarded once one knows things better, since its fuzzy "poetic" qualities—its incessant semantic oscillation as well as its suggestive figurativeness—pose a threat to scientific clarity.

Opponents of this linguistic purism have emphasized the creative potential in this essential ambiguity and claim an epistemic role for metaphor in scientific inquiry. According to this view, metaphors function not only as linguistic devices supplying a name where one is lacking, as they provide ways to describe new phenomena on the basis of those already well-understood, metaphors extend the body of scientific knowledge. As bridges between two so far unconnected fields of research, metaphors offer ways to explore their similarities, suggest promising research strategies and even may shape new terminologies. Thus, we have metaphors framing entire research fields, such as the brain-as-computer metaphor in cognitive psychology (Boyd 1979).

In contrast to Boyd and others, who mostly focus on single *theory-constitutive* metaphors, I have examined groups or *ensembles* of metaphors, and their interconnections within a whole theoretical architecture. Thus, far from providing one global symbol for the entire theory of evolution, Darwin's metaphors—*branching tree of nature*, *tangled bank*, *wedge*, and *war of nature*—taken together pose ways of understanding and highlighting different features of the theory.

*Themes* or *theory-constitutive* metaphors are in the public domain and are certainly shared by whole groups of scientists. I have been more intrigued by the metaphors that are used privately, as a resource in the creative person's struggle with ideas. Under the heading *Ensemble of Metaphor* we examine the development of representation in the creative work of a single individual as a system.

Here, it becomes apparent that metaphors should not be taken as outcomes of single-moment intuitions, popping up ready-made in the genius's mind, but as mental constructs with a history of their own: We witness Darwin's working and reworking the *branching tree*, we see him engendering various variants of the diagram, each contributing in a particular way to the development of the theory of natural selection. Moreover, the analysis of Darwin's *ensemble of metaphors* spells out what it means to equate metaphors with the scientist's tools of thought: The metaphor, commonly suspect for its shimmering semantic indeterminacy, paradoxically helps to shape still amorphous theoretical ideas and thus makes explicit their previously hidden implications: It is by means of the tree diagram that Darwin becomes aware of the exponential growth in the number of species and of the requirement to incorporate the concept of extinction into the theory of natural selection.

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The array of modalities available is not a constant. Modalities change, grow, and even disappear. Dramatic examples are Helen Keller's discovery of a language she could use to communicate with others, and the imagery used by a painter accidentally rendered color blind. But more commonplace examples of shifts or changes in modality are everywhere. If there is any significant, shared constraint on modality, it may be people's need to communicate with each other. Feynman, Schwinger and Tomonaga expressed and developed their ideas in very different modalities: visual-diagrammatic for Feynman, and algebraic for the others. But the obstacles to communication lasted only a year or so; in the end, with considerable help from Freeman Dyson, the imperative of communication prevailed.

# FROM PERCEPTION TO THOUGHT

The theme of this paper is that perception, as well as all other cognitive processes, can be better understood if they are reconsidered in their proper context, which is a temporally extended series of cognitive events; and the central problem—not solved, of course—is how do we get from one cognitive moment to another?

The psychology of thinking, for example, has often had an abstract, other-wordly character, unreal and remote from other cognitive functions. But thinking goes on in a creature who perceives and remembers. A great part of the constructive effort of thinking is aimed at re-creating the extraordinary vividness and immediacy of perceptual experience. We do this by building models, by searching for striking analogies and examples, and by more strictly imaginative acts. Even in dealing with these natural phenomena which are in principle inaccessible to direct perceptual experience, we try to reconstruct them "as though" we could actually see them. Thus, perception provides not only the source for our images, but a standard of vividness to which creative thinking can periodically return.

Just as our most immediate percepts are less equivocal because they are embedded in a time-series of other cognitive processes, our most creative thoughts are less bizarre and more vivid because they are embedded in a time-series of perception and exploratory actions.

The purpose of this paper is to consider some of the properties of the temporally extended stream of cognitive processes. Three topics will be considered: first, changes of cognitive modality; second, processes of cognitive transformation, of which modality changes are only special cases; and third, directional features of cognitive processes.

In the history of psychology a great deal of effort has gone into research which attempts to discover the unique substance of which thought is composed. Some of the substantive properties that have achieved experimental prominence are images, subvocal speech, and minimal muscular responses. All such efforts are doomed to that most horrible fate of all, partial success. For if one man in the world, even an experimental psychologist, believes that a given modality of cognition is the exclusive hallmark of thought, you may rest assured that it plays a part in his own thinking at least. His error lies only in his insistence on the uniqueness and exclusiveness of any one particular cognitive modality. For the most characteristic feature of the flow of cognitive process is its ceaseless shifting from one cognitive modality to another.

Within the perceptual domain, this is plain enough. The predominant aspect of experience is at one moment auditory, at another visual, and still another tactual. But this aspect of change is equally true of cognition in general. The predominant modality of cognition varies from moment to moment, from perception to imagery, to motor exploration, to the use of linguistic symbols, and so on, in a never-ending stream.

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A very simple example of a series of modality changes is the behavior of a hypothetical person solving a problem, such as straightening a picture which is not hanging properly. The "problem" is experienced in visual terms, and need never be formulated otherwise. A rather complex hypothesis and experiment are expressed in the motor activity of crossing a room and adjusting the picture. Only if this first effort fails will the use of language or other symbols appear, perhaps to review some of the laws of physics. Imagery may appear when our friend begins his search for a new piece of picture wire, and when he has located the wire in his *imagined* toolbox, he may switch once more to the level of motor activity.

Although this example is simple, it is far more complicated than the experimental examples I will present today.

In order to develop our description of the stream of cognitive events, we will need to introduce another concept: the notion of *transformation*. Our task is to get from one cognitive moment to another. We need a concept which speaks of continuity and novelty in the same breath. It is in that sense that I am using the term, transformation, and not in any more ambitious mathematical sense.

Every series of cognitive events begins with a net of elements in some configuration. There are probably a very great variety of transformations, but for the moment only a few broad classes will be indicated:

1. The elements may be preserved, while the relations are altered according to some definite rule.
2. The elements may be altered while the relations are preserved.
3. Mixed transformations, in which both elements and relations are changed.

Modality changes probably belong to this last group. On the one hand, it is obvious that modality changes involve changes in elements—that which is visual becomes tactual; that which is perceived becomes remembered; and, on the other hand, I think we shall probably discover that we cannot change the elements very drastically without also changing their configuration.

We need to know the kinds of transformation which commonly occur—a taxonomic task which will require great ingenuity; we need to know also the sequences in which they occur, and the conditions which evoke them. It is puzzling to decide how to begin such a study. We need to begin with some very simple examples.

Consider the behavior of a person in a picture gallery. He finds himself standing too far from a painting. He steps forward a few paces until he finds a viewing distance at which the aesthetic impact is greatest.

Stated in more general terms, the behavior sequence just described involves the transformation of spatial expansion. By the act of moving toward the picture, our picture-gazer spreads the image of the picture over a larger visual angle. Or, in Gibson's terms, the density of the image is decreased by moving toward the picture.

There are several noteworthy points here:

1. The picture remains phenomenally the same picture throughout this transformation.

2. The retinal images produced by the picture are perfectly isomorphic with each other throughout this transformation.
3. The transformation is accomplished by a change in the modality of psychological activity. The sequence in this particular case is visual-motor-visual.
4. In spite of the isomorphism mentioned above, the transformation produces something new: a changed aesthetic effect.
5. The transformation is a process in time.

Now let us suppose that our picture gazer is unable to step toward the picture. By surveying the picture and studying it awhile, he may be able to achieve an effect psychologically equivalent to the transformation of spatial expansion. This ability to achieve transformations in the domain of imagination which are the formal equivalents of changes in the physical stimulus input is of the greatest importance in understanding the continuity of cognitive processes.

Even the simplest features of this simple transformation need to be studied experimentally. Exactly what stimulus conditions evoke the motor part of picture gazing? How long does it take? Does the aesthetic outcome emerge gradually or suddenly? Perhaps a more interesting question—how does this transformation fit in with longer series of transformations?

I wish I could take time to describe an interesting experiment we have recently done, dealing with the transformation of spatial compression. The results suggest that the time necessary to achieve a perceptual organization is a U-shaped function of the density of the proximal stimulus.

In a vocabulary similar to that which I have employed here, size constancy is often described as the transformation in which compression of the proximal stimulus is coordinated with perceived displacement away from the observer, rather than with compression of the distal object. It is asserted that during the compression of the proximal stimulus apparent change in distance is in a reciprocal relation with apparent change in size. This argument goes far beyond the demonstration of size constancy and suggests that the ensemble of size and distance perception are the mutually consistent responses of a perceiver behaving as though he were a rational geometer.

There is no question about the occurrence of size constancy, but there is conflicting evidence about the occurrence of the reciprocal relation between perceived size and perceived distance.

We may have recently found the cause of this confusion. In a study of the relation between the assumed size of an object and its perceived distance, the much-vaunted reciprocal relation does indeed occur in some subjects, but not in all. Moreover, we have found that its occurrence is closely linked with the subject's ability to solve intellectual problems in geometrical optics.

Two points emerge from this kind of analysis. Perception is indeed stimulus-bound and in that sense objective. But specific perceptual outcomes depend on the operations of transformation which in turn depend on the subject's repertoire of transformations and on the choice he makes among them.

Although the admission of the terms, "repertoire" and "choice" guarantees the occurrence of error and subjectivity, it must always be remembered that perception is only one cognitive process embedded in a series of other cognitive processes. In the long run, the subject's sense of reality prevails, and perception does finally attain the distal object.

Among others, Vernon has recently dealt at length with some of the processes of cognitive elaboration by which this is accomplished. From this kind of approach, it would seem that perception becomes more reliable and more objective as it becomes less purely perceptual.

(The transformation of rotation can be studied in ways similar to the transformation of expansion-compression. Indeed, Wallach, in his experiments on the kinetic depth effect, has provided me with a very pretty study of this transformation, in which variations in physical stimulus input leave a residue in memory which is the formal equivalent of physical rotation. In an entirely different way, Professor Piaget has studied the transformation of rotation as it develops in the child.) This was omitted in reading.

The transformations mentioned above are essentially spatial, although I wish to emphasize that they occur as much in remembered and imagined spaces as in physically presented spaces. Let us turn now to a temporal transformation.

One of the most poignant features of scientific work is that we make our observations in a long-drawn-out way, spread over what sometimes seems a lifetime. Yet the patterns we are searching for cannot be comprehended unless those observations can be compressed and reexamined in a few seconds. Much of the effort and ingenuity of the successful scientist is devoted to rearranging his observations in just this way.

Sometimes it happens that good luck compresses observations for us. A striking case in the history of science in which the same coincidence, or temporal compression, produced identical results is the way in which contact with an archipelago catalyzed the development of evolutionary thought in the lives of Charles Darwin and Alfred Wallace. In Darwin's case it was the Galapagos, and in Wallace's the Malay, archipelago. The significant feature of an archipelago for our purposes is that small differences in species are separated by only small distances between islands, so that the species differences can be observed in rapid succession. Thus, nature combined with sailing ships to provide the conditions for the transformation of temporal compression which might otherwise have consumed a lifetime of intellectual struggle.

But we should not overemphasize the external stimulus conditions. The hallmark of scientific thought is that it can reproduce the same transformation at will, over a much wider range of conditions.

In order to study the transformation of temporal compression in the laboratory, a very simple situation was devised. We used a series of ten short sentences, spoken at varying speeds. Each sentence had thirteen one-syllable words, and in every case the individual words were pronounced in a normal way. The stimulus variable, then, was the interval between words. For a given sentence the interval was constant, and the speeds at which the sentences were spoken varied from normal speed to six second interval between words. Here is a sample sentence:

"I—came—to—class—and—missed—the—first—part—of—his—talk."

The subjects were instructed to listen to the sentence, write it down when given a signal, and then to describe "what was going on in your mind while the sentence was being spoken and just afterwards, before you started to write it down." There were thirty-six subjects. Their responses were later classified in fifteen sub-categories. Only three major categories need concern us here: first, sub-vocal repetition, during the presentation of the stimulus, of some or all of the words already spoken; second, visual imagery of scenes represented by the sentence or of the words composing the sentence; and third, anticipation, or guessing the next word to be presented.

The results were as follows: Every subject reported that he repeated words and groups of words in some of the sentences. Under the conditions of this experiment, the threshold interval for this form of temporal compression was approximately one second. As might be expected, such sub-vocal repetitions hardly ever occur when the stimulus is a normally spoken sentence. Needless to say, the sub-vocal repetitions occur at a rate which is faster than the stimulus rate. It is in this sense that we can speak of the transformation of temporal compression.

It can be said that this transformation is accomplished by means of a change in cognitive modality, as sub-vocal repetition is quite different from the direct auditory apprehension which occurs in listening to normally spoken sentences. But a further modality change occurred for some subjects. Over half of the subjects reported using some sort of visual imagery in at least some of the sentences. Although we do not yet have enough data on this point, it seems fairly certain that the threshold interval for visual imagery is about twice as long as the threshold interval for sub-vocal repetition.

Another response category, guessing the next word to be presented, gave results quite similar to those for visual imagery.

One additional group of subjects was instructed to refrain, if possible, from making any of the responses described above, but to report after each sentence in the same manner as the other groups. This instruction to refrain from making cognitive responses was completely successful in suppressing reports of visual imagery, partially successful in suppressing anticipation, and had no effect at all on the results for sub-vocal repetition.

This experiment, in addition to demonstrating the transformation of temporal compression, brings out one other very interesting point. These transformations are often, if not always, mediated by changes in cognitive modality. The particular choice of modalities is not arbitrary, but depends on the specific characteristics of the stimulus. In the transformations discussed above, modality changes are prominent but possibly incidental properties of the transformation. I would like to cite one last transformation in which a change of cognitive modality is the central issue. This is a striking experiment by Dijkhuis, and deals with transformations from the domain of auditory stimuli to a domain of imaginary visual events.

The subjects were asked to identify various auditory stimuli. For example, the stimulus might be a two-dimensional geometrical form or a letter of the alphabet scratched on a board with a stylus.

Subjects were very successful in this task, except for errors such as the confusion of W, H and ◊, where the stimuli are in fact auditorily identical.

Dijkhuis presents some important evidence to make his point that the transformation is from an auditory domain to a quasi-visual domain. Subjects born blind could not perform this task at all, whereas sighted subjects and accidentally blinded subjects performed about the same; that is, with a high degree of success. Needless to say, the subjects born blind performed extremely well in other auditory recognition tasks, such as recognizing the sound made by pouring water into a glass, where only the recognition of characteristic sounds of objects was required, rather than this quasi-visual transformation.

The errors made by the sighted subjects are interesting too. They bring home the point that, in mapping from one modality to another different features of the object or event in question are lost and gained, masked or emphasized. The object or event as we eventually come to know it, is not psychologically given by one prototypical form, but by the entire set of transformations that we are capable of working on it. In the last analysis, that is why perception cannot be isolated from other cognitive functions.

This discussion of the relation between perception and thinking might easily have begun by likening perception to problem solving, as Woodworth and Schlosberg have done, or conversely, by likening thinking to perceptual gap-filling behavior, or completion phenomena, as Bartlett has done. But I think that this is a separate and a subsequent step. First we need to consider the development of cognitive configurations in order to understand how problems and gaps sometimes arise in them. Problems and gaps need not always be taken for granted and introduced into our research designs at the outset. The emergence of problems within the ever-changing cognitive stream is itself a problem, and we know very little about it.

To sum up, in the language of today's symposium:

Perception and thought are different ways of knowing, different forms of cognition.

It has long been known that the various forms of cognitive activity influence each other.

The fact is also that they follow each other in a temporal sequence, and that the embedding of the various forms of cognitive activity in a temporal stream is the means by which the human organism achieves its unique compounding of objectivity and creativity.

# Darwin's "Tree of Nature" and Other Images of Wide Scope

When we speak of the aesthetic attitude in science we have in mind aesthetic criteria that apply to the main results of scientific work, the perception of comprehensible order or pattern in some part of nature. We think of appropriate stories linking art and science in their appetite for pattern—a friend wishes to awaken the sleeping Mozart; he plays an unresolved progression of chords; Mozart jumps up, rushes to the piano, finishes the sequence. We resonate to the aesthetic motive behind Einstein's "God does not play dice with the world." (Not so different from the remark of an earlier physicist, Sir John Herschel, who complained that Darwin's theory of evolution was "the law of higgledy piggledy" (Darwin 1887, 241)). Coupled with this aesthetic mood is a certain admiration for the heroic objectivity of scientists, their obstinate search for a place to stand from which to see into nature's order.

But behind these orderly results, which are after all our results and not nature's, lies nature itself, much wilder; and underneath them lies the often messy, inchoate processes of scientific thought. Is not our evident aesthetic pleasure in wild nature a part of the "aesthetics of science"? And are there not aesthetic feelings that apply, not only to the product but to the process of scientific work? And if so, do we invoke the same aesthetics of objectivity, simplicity, harmony, and order, or do we need another kind? Is there not also an aesthetic mood of erotic wildness, passionate involvement, pleasure in complexity and unpredictability? And if so, has this second aesthetic mood a place in science?

Others have made roughly similar distinctions: Herbert Read (1965), the vital and the beautiful; Alex Comfort (1962), soft- and hard-centered; Sylvano Arieti (1976), borrowing from Freud, primary and secondary processes; or simply romantic and classical. Such dichotomies are only approximations suited to their authors' purposes. Aesthetic experience and aesthetic process are many-faceted ensembles. They might submit to description by means of multivariate profiles. For the moment, then, I need make only a provisional and very rough dichotomy to help me get on with my argument.

Alex Comfort begins his essay, *Darwin and the Naked Lady*, with a quotation from Paul Eluard, "*Rêve et réalité—la rose et le rosier*." Of course, Eluard meant *ideal* rather than *dream*, certainly not the fantasmagoric dreams of troubled sleep. In any event, for biological science the perfection of the rose and the tangle of the rose bush are both part of reality. If we want to grasp the aesthetic side of scientific work, it will not do to seize on one or the other. It is in their lively interplay that understanding moves forward. Since this interplay must inevitably take place within one person's experience, it is well to look steadily for a while at one person and to study these different kinds of aesthetic moments as they bear upon each other.

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Among scientists, Charles Darwin is a useful subject. A critical period of his life were the years 1837-38; he was just back from the five-year voyage of the *Beagle*, he was twenty-eight years old, and he launched himself into a fifteen-month effort during which he constructed the essentials of the theory of evolution through natural selection. For this period he left us a set of revealing notebooks.[1] These permit us to see him in many moods at different junctures in the growth of his thought.

Darwin is a strategic choice for another reason. The meaning of his whole life work is saturated with the duality under discussion. On the one hand, he wanted to face squarely the entire panorama of changeful organic nature in its amazing variety, its numberless and beautiful contrivances, and its disturbing irregularity and imperfections. On the other hand, he was imbued with the spirit of Newtonian science and hoped to find in this shimmering network a few simple laws that might explain the whole movement of nature.

In the pages that follow I want to elaborate this theme and then illustrate it with examples drawn mainly from one generally neglected feature of scientific thought, the use of images of wide scope. These images are not usually part of the formal, consensus-minded part of science. They are more personal and therefore allow more room for the fruitful interplay of several aesthetic moods. I hope to draw together these two ideas, the interplay of different aesthetic moods in scientific thought, and the notion of images of wide scope.

## ON THE EXISTENCE OF DIFFERENT AESTHETIC MOODS IN SCIENCE

It seems hardly necessary to insist on the existence of the first mood, except to contrast it with its less often noticed companion. But a few reminders may be in order.

The search for an aesthetics of simple forms has an old history. As soon as the psychophysical methods were invented by Gustav Fechner, he applied them to the search for the proportions of the most pleasing rectangle. Although artists and designers have long known of the "golden section" (a rectangle whose proportions can be described by a simple mathematical formula), and although a presupposition in favor of it motivated early research, a general preference for it has not been easy to demon-

1. There are two sets of notebooks, those on evolution per se and those on associated issues concerning man, mind, and materialism (DeBeer 1960-61/67). These are referred to in the text as *First Notebook*, *Second Notebook*, etc. The notebooks on man, etc. are published in full in Gruber (1974). There was also a field notebook, mainly on geological matters but with a few observations on animal breeding, that Darwin kept during 1838. No transcription of this has yet been published, but it is described in Rudnick's excellent account of Darwin's struggle with a major geological puzzle that had a bearing on his general point of view: the peculiar "parallel roads of Glen Roy," which led Darwin to make a field trip to Scotland in July of 1838, the same month that he began the notebooks of man, mind, and materialism (Rudwick 1974).

strate. Nevertheless, the idea that there is some simple ratio describing the most pleasing proportions of any general form has been a seductive starting point for investigation.

Gestalt psychologists have emphasized perceptual tendencies toward closure, simplicity, and prägnanz. This last is hard to define but can be captured by the idea that we tend to see objects as being more like the ideal types they resemble than they really are. Thus, a slight departure from perfect circularity is still seen as a circle, etc.

When I was a student, we did not examine the aesthetic or other motives of scientists in any serious way. We were not asked to read, think, or write about the subject. It never occurred to me to doubt the occasional impassioned allusion to the connection between the search for beauty and the search for truth. Neither did it occur to me that there was any pressing need to study the matter: enough that I often felt a surge of pleasure at a pretty result or a beautiful idea.

But I did absorb a certain attitude toward the subject, one that fitted in pretty well with my own aesthetic preferences. What is beautiful in general and therefore beautiful in science is harmony, order, simplicity, a quality of cleanness. There was certainly not enough discussion of the subject to sort out two questions: Are we talking about beauty in nature or beauty in scientific work and thought? But if we had done so, we probably would have applied the same aesthetic criteria to both. The order of the scientific mind reflects the order of nature.

As time has gone by, the recognition of the importance of aesthetic values in scientific work has grown in me. At first this was an easy and welcome change, for the material I was drawn to happened to fit well with the clean aesthetics of simplicity. But more recently I have become increasingly aware that there is another interesting set of aesthetic attitudes. Things can be beautiful precisely because they are complex, unpredictable, imperfect, erotic.

Having begun with an admiration for Max Wertheimer's characterization of productive thinking as "fine, clean, direct" (Wertheimer 1945), I was taken by surprise in my work on the growth of Darwin's thought to find that it was tortuous, tentative, enormously complex, full of unwarranted assumptions, and in a sense quite "dirty." At the same time, I saw that Darwin's picture of nature as an irregularly branching tree attributed to nature some of the characteristics that I saw in his thinking. One might sidestep a difficult aesthetic decision here by cleaving to "clean" aesthetics as it applies to the products of scientific thought; we could admit that the process is "dirty" while the product, such as Darwin's theory of evolution through natural selection, is clean and beautiful. Similarly, if we consider the scientists' view of beauty in nature itself, we might agree that nature is endlessly complex and aesthetically ambiguous, while beauty, residing in the eye of the beholder, is represented only by the simpler harmonies and patterns we can detect when we examine it in the quiet of the mind or the laboratory. Such distinctions may be useful if they help us to see that it is the concrete interaction among these different kinds of events that produce any particular aesthetic process.

No one reading the *Origin of Species*, especially the celebrated closing paragraph describing "the tangled bank" (Darwin 1859, 489-490), can fail to notice that Darwin took pleasure in the spectacle of complexity itself. And not only the complex entanglements of organisms at a moment in time, but the further manifold of intricacy residing in the meandering evolutionary path of every organism and every organ. Thus, on the side of the scientist's view of nature, here is at least one important figure whose image of nature itself is one of irregularity and entanglement. Moreover, he elaborates this image repeatedly over many years, with evident pleasure in ways that suggest an intimate connection between visual and poetic imagery and productive scientific thought.

When we consider the scientist thinking, we cannot escape the aesthetics of complexity. As we come to understand the intricacy of the course of thought, some of us admire it and find it all the more beautiful. As we see its unfinished character and the struggles of the scientist with a task which is inevitably and tragically beyond his grasp, other aesthetic values come to the fore. There is little prospect that our picture of creative thinking will grow simpler in the near future. We have just begun to uncover its seductive labyrinths.

But scientific thinking is not simply an object of investigation, it is also the lived experience of scientists. If in our role as spectators we can enjoy its wildness, so can we in our role as scientists, and so can our colleagues. Thus, the taking of pleasure in wildness is available to the whole intellectual community.

For a long time nothing so offended the aesthetic sensibilities of many scientists as the suggestion that the world was not perfectly orderly. When Herschel disdainfully described Darwin's theory as the "law of higgledy piddledy," this was not only an intellectual objection to the introduction of the idea of chance into a scientific theory but an aesthetic reaction as well. This is clear from Herschel's other remarks (Darwin 1903).

But chance is a very broad concept that works in varying ways. A large number of similar events may produce a beautifully "simple" and predictable result, such as the smoothness of a Gaussian curve or the sphericity of a gas-filled balloon, and we may well admire such simplicity and regularity (either directly as a child does, or more sophisticatedly in taking note of both the simplicity and its underlying manifold). But the panorama of nature finds chance working in other ways where the results are neither simple, perfectly harmonious, or predictable. A real taxonomic tree has no simple order, and we must take our pleasures where we can—in our ability to make out its tortuous multiformity.

## DARWIN'S IMAGERY

Recently I visited an exhibition of anamorphoses at the Brooklyn Museum: Distorted images are seen as normal when viewed from a special station point or when reflected in a cone or cylinder. One may see at the center of a picture a cone with a mirrored surface, surrounded by a distorted, unrecognizable image. At first, there is a tendency to glance perfunctorily at the distorted image, say of a human face or body, and then to study attentively the "corrected" version seen from the appropriate position. After a while, however, the distortions themselves draw the attention as objects of aesthetic interest. They have their own, sometimes weird, ugly, fascination. There is more to anamorphoses than a complex game of mapping a transformation. The artists who have played this game over the centuries are telling us something serious: nature has many faces, some harmonious and pretty, others wild and ugly.

It was precisely this duality that gave Darwin's contemporaries so much difficulty. Why would the Divine Artificer deliberately endow the natural order of His Creation with so much imperfection—hatred and violence, pestilence and death? How could these inescapable facts be reconciled with the image of a harmonious and perfect order of nature, the work of an omnipotent and benevolent Creator? There were various theological answers to the puzzle, and Darwin was thoroughly exposed to them in his university education. But when he begins his notebooks on evolution, we see from the first page that he has set himself the task of finding a completely natural solution to the dilemma. "Why is life short?" (*First Notebook*, p. 2). Why the cycle of birth, growth, reproduction, and death? His answer: to eliminate imperfections acquired in the life of the individual, "... generation destroys the effect of accidental injuries, which if animals lived for ever would be endless ..." (p. 4). At the same time, the reproductive cycle permits adaptation: "There may be unknown difficulty with *full* grown individual with fixed organization thus being modified,—therefore generation to adapt and alter the race to changing world" (p. 4, Darwin's italics). Thus, the function of the life cycle has a double aspect, to preserve the near-perfect adaptation already achieved, and to permit the organism to change when necessary.

From this vantage point Darwin moved quickly to his first theory of evolution, which I have described in detail elsewhere (Gruber 1974). Monads or simple living forms arise through spontaneous generation; they evolve as they adapt to changing circumstances. Because of the fortuitous nature of their encounters with a changing world, their evolution takes the form of an irregularly branching tree. "Organized beings represent a tree, irregularly branched ... As many terminal buds dying as new ones generated. There is nothing stranger in death of species, than individuals" (p. 21, Darwin's italics). In quick succession, he makes three tree diagrams, each capturing somewhat different features of the idea that is growing in him. The first (Figure 1., upper diagram) emphasizes the idea of a triple branching: "Would there not be a triple branching in the tree of life owing to three elements—air, land and water, and the endeavour of each typical class to extend his domain into the other domains and

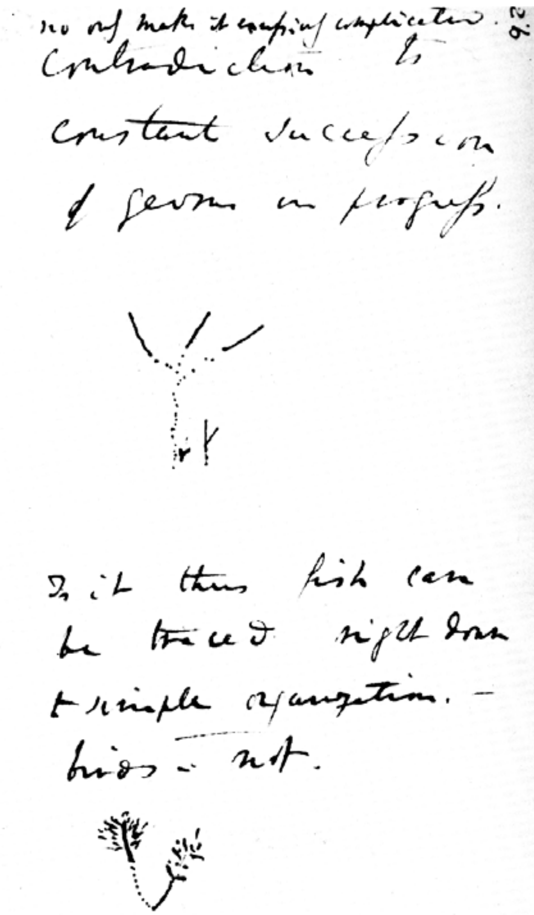

*Figure 1.* Darwin's first two tree diagrams, on page 26 of the *First Notebook*. Immediately preceding the upper tree the MS reads, "the tree of life should perhaps be called the coral of life, based on branches dead; so that passages cannot be seen.—[end of p. 25, beginning of p. 26] this again offers ((no only makes it excessively complicated)) contradiction to constant succession of germs in progress." Words in double parentheses were inserted above the line by Darwin. Immediately preceding the lower tree the MS reads, "Is it thus fish can be traced right down to simple organization—birds—not."

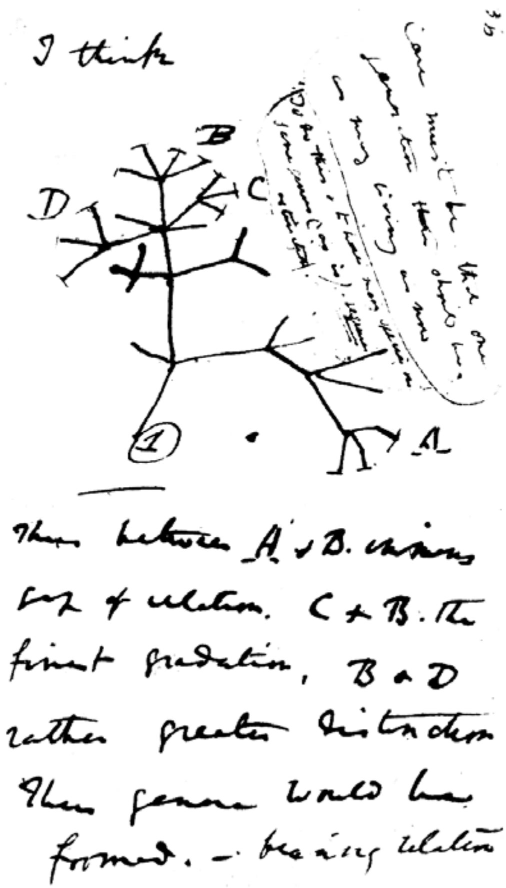


*Figure 2.* Darwin's third tree diagram, on page 36 of the *First Notebook*. The MS reads, "I think" followed by the diagram. Then, "Thus between A & B immense gap of relation, C & B, the finest gradation, B & D rather greater distinction. Thus genera would be formed,—bearing relation [end of p. 36, beginning of p. 37] to ancient types." The marginal insertion alongside the tree diagram reads, "Case must be that one generation then should have as many living as now. To do this & to have many species in same genus (as is), requires extinction."

subdivisions, three more, double arrangement. If each main stem of the tree is adapted for these three elements, there will be certainly points of affinity in each branch" (p. 24). This diagram and passage reflects certain general taxonomic problems Darwin was hoping to solve within the framework of his theory.

The second diagram (Figure 1., lower diagram) emphasizes the long gaps in the fossil record, a long dotted line showing a continuity between hypothetical extinct (but unknown) forms and the seemingly sudden efflorescence of a later group of organisms.

In the third diagram (Figure 2.) Darwin introduces a specific notation to indicate a fundamental feature of his tree of life, extinction. Extinction was by no means a universally accepted idea, even among evolutionists. Lamarck had vigorously denied it. Darwin well knew that the fact of extinction is hard to prove, since it is founded on negative evidence—that is, the failure up to a particular moment in scientific time to find living specimens of an organism known to have once lived. Negative evidence is risky, counts for little. But Darwin had already begun to see that his tree image is a picture of exponential growth in the number of species, and this poses a problem for him that can only be solved by the idea of extinction. Thus he was at pains to show that extinction was not simply a fact but a formal requirement of his system. "I think Case must be that one generation then should have as many living as now. To do this and to have as many species in same genus *requires* extinction." (p. 36, Darwin's italics).

In short, the branching model, the image of the irregularly branching tree of nature played a pivotal role very early in his thinking about evolution. It captures many points: the fortuitousness of life, the irregularity of the panorama of nature, the explosiveness of growth and the necessity to bridle it "so as to keep number of species constant" (p. 37). And most important, the fundamental duality that at any time some must live and others die.

It took about fifteen months from this point until Darwin grasped the principle of natural selection as a key operator giving the tree of life its form. While Darwin's thought changed in many ways from these earliest notes until the time, some twenty years later, when he wrote the *Origin of Species*, this image of nature remained constant. Essentially the same tree diagram as his Figure 3 appears in the *Origin* (1859, 116). It is the only diagram in the book, and it is referred to throughout as he exploits its theoretical richness, some of which I have indicated.

Over the years, Darwin drew and redrew the tree diagram. I have paid attention to the scraps of paper in his manuscript on which these diagrams can be found, some dateable, others not. Some of them are hasty sketches, others painstakingly drawn and delicate traceries. On one such scrap there is the remark, "Tree not good simile—endless piece of seaweed dividing." He is probably not so much correcting himself as searching for the right variant of his image to express a particular idea that has caught his attention, just as in the *First Notebook*, after his first drawing he wrote, "The tree of life should perhaps be called the coral of life, base of branches dead, so that passages cannot be seen" (p. 25).

We have seen how Darwin's view of the functional significance of the life cycle is connected with his panoramic view of nature as a whole. It is not often enough brought out that there was a certain cosmological cast to Darwin's thinking. Influenced, perhaps intimidated, by the empiricism of his day, Darwin later suggested that he worked in a "Baconian" fashion, inductively from facts to theory. His notebooks do not bear this out. He sketched his ideas with a broad brush and often drew a long bow. Thus, "Astronomers might formerly have said that God ordered each planet to move in its particular destiny. In same manner God orders each animal created with certain form in certain country, but how much more simple and sublime power let attraction act according to certain law, such are inevitable consequences—let animal be created then by the fixed laws of generation, such will be their successors. Let the powers of transportal be such, and so will be the forms of one country to another.—Let geological changes go at such a rate, so will be the number and distribution of the species!!" (pp. 101-102). In Darwin's image of the world, the life cycle and the evolving tree of life are nested in a larger view of the working of the cosmos.

It may be argued at this point that Darwin's diagrams are only conceptual tools for theoretical thought and have no aesthetic significance. Then why the evident pleasure in the actual drawings, the constant search for the right metaphor, the emotional excitement conveyed by his punctuation and frequent resort to a high-flown style? There is exactly that combination of feeling with concern for form and content that we have in mind when we speak of an aesthetic act. As well say that anamorphoses are not art, or that Dürer's use of instruments or Leonardo's studies of human anatomy have no aesthetic significance. Only if we presuppose a divorce between art and scientific thought would we be tempted to turn a blind eye to the aesthetic side of Darwin's imagery.[2]

If the irregularly branching tree of life is Darwin's image of nature deployed in evolutionary time, the "tangled bank" of his eloquent closing paragraph of the *Origin of Species* represents his image of the same explosive vitality in all its complex interconnectedness at one moment in time. It was this passage that gave the title to Stanley Edgar Hyman's lovely book (1962) about the relation between intellectual work and literary imagination. Although foretastes of this passage occur in the notebooks and in the preliminary sketches of the *Origin* Darwin wrote in 1842 and 1844 (1909), the precise image of the tangled bank does not. Nevertheless, Darwin's fascination with the intricate web of contemporaneous relationships among organisms is evident as early as the notebooks of the *Beagle* voyage (1831-36) (Gruber and Gruber 1962) and appears in many forms long before the *Origin*. In the carefully drawn-up table of contents of the *Origin* there occurs the striking phrase, "The relation of organism to organism the most important of all relations." This idea is spelled out in some detail in the text.

This is of course not an idea original with Darwin. It can be found in many places, notably Gilbert White's *Natural History and Antiquities of Selbourne* (1789). It is nonetheless an idea essential to Darwin's thinking.

But interconnectedness does not by itself mean imperfection. Among Darwin's immediate precursors, in Lamarck's thought, in German *Naturphilosophie* and in English Natural Theology, the idea of perfection was deeply embedded. In the first

2. A number of writers have discussed the relation between schematization and art, none of them suggesting a dichotomy. See Arieti (1976), Read (1965), and Arnheim (1969), and Gombrich (1960).

two it took the form of a scale of increasing perfection toward some limit or ideal type, that is, man, as in Lamarck's ladder of nature. The Natural Theologians could not accept this formulation because it meant that some of God's creation was less than perfect. In their view every organism was perfectly adapted to its place, seeming imperfections simply showed the limitations of our understanding of His work. Darwin's view of the natural order as inherently irregular, incomplete, and imperfect differed as radically from his predecessors as did his view of the process by which this came about.

Thus two great and vital images, one of historical, the other of contemporary relations, form the substrate for the theory of evolution by natural selection. They are not, however, merely background, but are woven explicitly into the theory as presented in the *Origin*.

The irregularly branching tree and the tangled bank represent the vital complexifying aspect of Darwin's thought. Other images must be sought that express the simplifying aspect. Of all those things that might occur in nature's incessant branching, some never do at all. The extinction of one evolutionary line makes impossible all the species that might have evolved from it. Of all those transient relations depicted in the tangled bank, some endure and others disappear. As we have already seen, the necessity for some principle of selection almost leaps out of these images.

In *Darwin on Man* I have carefully spelled out the slow process by which the thinker constructs the mental circumstances of his own insights. In considering even a most important moment of insight, this slow phase of construction must not be forgotten. On the other hand, such moments do occur and they deserve our attention. As is well known now, on September 25, 1838, Darwin, after reading (or perhaps rereading?) Malthus' *Essay on Population*, finally saw the principle of natural selection in a clear way. The passage in his notebook where he writes this out conveys the feeling of the moment as it was happening. It contains a striking and brutal mechanical image: "One may say there is a force like a hundred thousand wedges trying [to] force every kind of adapted structure into the gaps in the economy of nature, or rather forming gaps by thrusting out weaker ones" (*Third Notebook*, p. 135). The image reoccurs in the sketches of 1842 and 1844. In the first edition of the *Origin* it is heightened: "The face of Nature may be compared to a yielding surface, with ten thousand sharp wedges packed close together and driven inwards by incessant blows, sometimes one wedge being struck, and then another with greater force" (p. 67). This image has two features. On the one hand it emphasizes the idea that the theory deals with the interplay of a multitude of small forces rather than with the clash of Titans (in this way the theory is quite unlike Freud's depiction of struggle between Eros and Thanatos). On the other hand, the wedging image brings out the incessant rupturing of the seeming harmony of nature. Oddly, this image disappears from later editions of the *Origin*. It is as though Darwin needed to insist on this brutal rupturing but then recoiled a little from the hard mechanical nature of his image.

In the *Origin*, of course, two other well-known images occur. Human warfare, in Malthus' treatise the actual subject matter, becomes for Darwin one of the images he draws upon. For us the idea of warfare may seem to evoke the prodigal "wastefulness" of nature. For Darwin, there is a different emphasis. The image brings out the magnitude of the selection ratio of those that die to those that survive to reproduce. But Darwin's whole point is that this is not wasteful but creative, nature's way of fashioning the many ingenious contrivances embodied in every organism. Besides, if we avoid anthropocentrism, in the struggle for existence nothing is wasted. Those that die are eaten. Darwin is explicit on the way in which he intends the image of struggle to be taken: "I use the term Struggle for Existence in a large and metaphorical sense ..." (Darwin 1859, 62)—covering many shades of meaning from actual combat between two organisms to simple dependence on conditions of life such as climate.

Finally, there is the metaphor of artificial selection. In one sense, Darwin's deep interest in artificial selection represents his desire to submit his theory to experimental test. Darwin was an inveterate experimentalist, and it must have troubled him that the theory as a whole could not be so tested. Human efforts to breed plants and animals come as close as possible. Darwin was, however, keenly aware of the many differences between artificial and natural selection, and his examination of the former, placed with poetic strategy in chapter 1 of the *Origin*, "Variation Under Domestication," has a clearly metaphoric intent. This metaphor plays a specific role in the theoretical structure, to emphasize the cumulative nature of evolutionary change. Darwin concludes the chapter by remarking that, of the several possible causes of change that he has discussed, natural selection is the most important:

"Over all these causes of Change I am convinced that the accumulative action of Selection, whether applied methodically and more quickly, or unconsciously and more slowly, but more efficiently, is by far the predominant Power" (*Origin*, p. 43).

There are then at least these five images that Darwin used in developing the theory of evolution through natural selection—tree, tangled bank, wedging, war, and artificial selection. One of these, wedging, Darwin himself dropped from later editions of the *Origin*, so it is no wonder that it has been forgotten. Of the remaining four, only two are commonly referred to in discussing Darwin's theory—war and artificial selection. Both of these are simplifying images, dealing with the selective and corrective side of the process. The other two images, all too often forgotten, dramatize the principle of vitality, the explosive, irregular living material on which selection works.

For the moment, I simply want to draw attention to two points.

First, the multiplicity of these images. Second, the specificity of their functions in the theoretical structure. Earlier we saw that each drawing of the tree of life had specific features highlighting one or another aspect of the theory at an early stage of its development. Now the same can be said of Darwin's use of images in the definitive construction of his theory. They are not multiplied as a display of virtuosity but used with poetic economy, each image making its point, each point finding its image.

## THE EROTIC STRAIN IN SCIENTIFIC THOUGHT

Up to this point the discussion has been entirely cognitive: images generate ideas and ideas clarify images. But there is an affective aspect of the same work. We need to ask a new set of questions. Why did Darwin look so long and intently at nature in the first place? Why did he work so hard at science, care so much? It will not be necessary to go into unknown details of his early personality development to address the question of Darwin's emotional relation to science in some useful way.

As a result of certain lines of psychological research and a general readiness to accept the idea, it has become a widespread tendency to emphasize the role of theory in guiding scientific observation. "Observation is a theory-laden undertaking," insisted N. R. Hanson (1958), and Thomas Kuhn (1962) has emphasized the same point. But one ought not slip carelessly from accepting this idea into believing that the connection between theory and observation is such that the former dictates the latter, for that would destroy the point of observation. Nor ought we slip into believing that an individual must have a clear or mature scientific theory before he can make valuable observations. The process of mapping data into scientific theory is a social process with many byways. It is possible, for example, for one person to make observations that another will explain.

The need for these cautionary remarks occurred to me from a simple fact in Darwin's life. He was a fine and eager observer before he was a great theoretician. The whole of his boyhood and adolescence at Shrewsbury, Edinburgh, and Cambridge attest to this. It is not only evident from his *Autobiography* (1958) but from the still unpublished field notebooks he kept even before he went to Cambridge. We need to account for the passion with which Darwin regarded nature without recourse to our knowledge of his later theoretical work. Something of the intensity of this passion is conveyed by the story of one of his entomological exploits: "But no pursuit at Cambridge was followed with nearly so much eagerness or gave me so much pleasure as collecting beetles. It was the mere passion for collecting, for I did not dissect them and rarely compared their external characters with published descriptions, but got them named anyhow. I will give a proof of my zeal: one day, on tearing off some old bark, I saw two rare beetles and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas it ejected some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost, as well as the third one" (Darwin 1958, 62). He was about eighteen years old then. Earlier at Edinburgh University he had taken part in the Plinian Society and made a few discoveries that found their way into print. Something energized young Darwin so that he looked at things of nature more often, more lengthily, and more intently—with greater passion—than the other young gentlemen of his acquaintance.

Carrying the story forward a little in time, during his last years at Cambridge and the early years of the voyage of the *Beagle*, Darwin was enamored of the writings of Alexander von Humboldt. At Cambridge he liked to read Humboldt's prose-poetic descriptions of nature aloud to his friends. On arriving in Brazil he wrote,

> Humboldt's glorious descriptions are & will for ever be unparalleled: but even he with his dark blue skies & the rare union of poetry with science which he so strongly displays when writing on tropical scenery, with all this fall far short of the truth. The delight one experiences in such times bewilders the mind; if the eye attempts to follow the flight of a gaudy butter-fly, it is arrested by some strange tree or fruit; if watching an insect one forgets it in the strange flower it is crawling over; if turning to admire the splendour of the scenery, the individual character of the foreground fixes the attention. The mind is a chaos of delight, out of which a world of future & more quiet pleasure will arise. I am at present fit only to read Humboldt; he like another sun illumines everything I behold. (Darwin 1934)

Here then is the "tangled bank" in an early form, almost a direct observation of it, not illuminated by a theory but by a poetic traveler. It is noteworthy that Darwin retained for so many years the capacity to enjoy both the "chaos of delight" and the quieter pleasure that followed from reflecting upon it.

Throughout his life, then—before he had any sort of theoretical position of his own to go on, before he had a "good" theory, and after—Darwin looked at nature with deep emotion. This was not disruptive but a positive force in his life. He saw well.

Among his earliest encounters with science was the reading of his grandfather's poetry. It is interesting that Dr. Erasmus Darwin was an evolutionist who propounded a theory something like Lamarck's. But it was probably more important for Charles Darwin that much of his grandfather's account of nature took a poetic form, and that much of this poetry was explicitly sexual. It is not today ranked as good poetry. In my own first reading of it, much of it seemed little better than doggerel. But as I read on, steeped myself in it, tried to feel it from young Darwin's point of view, I did not find it difficult to be moved, and to understand what a profound effect it might have had. It was poetry deliberately intended to excite the reader's passion for nature and for science, ranging from abstract ideas to close descriptions of sexual reproduction in plants. As befits poetry, the latter were cast in personified form, often so vivid that it is easy to forget that Dr. Darwin is not writing about human sexual behavior. Even in *Zoonomia*, the prose work in which he presented his theory of evolution, there is often a poetic ring. The chapter on instinct closes with the line, "Go proud reasoner, and call the worm thy sister!" (Darwin 1800, vol. I, 219). It was exactly this poetic admonition to which Charles Darwin devoted his life and his passion.[3]

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3. There is much more that could be said of Darwin and poetry. During the voyage he carried Milton's Paradise Lost in his pocket on his expeditions ashore. No one has traced out the connections between Darwin and Milton in any detail. A full work on the poetic vein in Darwin's thought remains to be written.

## IMAGES OF WIDE SCOPE

We have seen that Darwin's thinking is characterized by the interplay of different aesthetic moods, and that the vehicle for much of his thought is a group of images of wide scope. An image is "wide" when it functions as a schema capable of assimilating to itself a wide range of perceptions, actions, ideas. This width depends in part on the metaphoric structure peculiar to the given image, in part on the intensity of the emotion which has been invested in it, that is, its value to the person.

Academic psychologists have contributed little to this subject. Most do not touch upon it at all. Even when dealing with the subject of imagery they limit themselves to representations of specific objects. But in trying to keep up with their colleagues in kindred sciences, they are coming closer to this topic. In Ulric Neisser's recent book, *Cognition and Reality* (1976), it is significant that in discussing this subject he must draw upon the work of sociologist Goffman, mathematician Minsky, architect Lynch, and anthropologist Gladwin. One of his two main examples is taken from Gladwin's *East Is a Big Bird* (1970), describing the way in which canoe navigators of the Puluwat Islands in the Pacific form an image permitting them to represent the relationships among stars, island landmarks, and ocean positions. His other example is taken from Lynch's book, *The Image of the City* (1960), representing the experience of a city by its inhabitants. Neither example is an image of the future or of the past or of an entirely imaginary world. (But Oscar Wilde wrote somewhere, "A map of the world that does not include Utopia is not worth even glancing at, for it leaves out the one country at which Humanity is always landing.")

For the most part the study of the role of images of wide scope in scientific thought has fallen between two stools. On the one hand, psychological examination of scientific thinking has been a process-oriented enquiry, aimed mainly at treating it as a variety of problem solving. The actual content of scientific thought has not been deemed part of the real subject of investigation. Only recently, and in good part through the development of computer science, has it been recognized that ways of representing complex contents are inescapably part of the process too.

On the other hand, the psychological study of images has been mainly limited to images of specific objects. After a long period of disrepute, the notion of image has become newly respectable, and even prominent but only in a restricted way. For example, a person properly instructed can concoct combinations of images of specific objects linking the items in a series of terms to be remembered, thus greatly improving his performance in a recall task. But the study of large and complex images has not yet been taken up with any vigor.

Yet it is almost obvious that the contents and therefore the process of scientific thought include a great deal of imagery. Many of the images in question represent things unseen and unfelt, and some of them represent things which, in the thinker's own conception of them, are nonexistent. Although psychologists have neglected the subject, Kenneth Boulding in his book, *The Image*, wrote, "It is the capacity for organizing information into large and complex images which is the chief glory of our species" (Boulding 1956). Although Boulding speaks of "information" he does not mean to restrict his remark to images of the real world. It is part of his thinking about the subject that the human stock of images includes self-conscious information about the products of imaginative construction.

What is the function of such complex imagery? Boulding, Miller, Galanter, and Pribram (1960), Minsky (1975), and others have treated them as indispensable for the activity of ordinary life. Information is organized in complex packages, schemas, or frames, and these are activated as needed. New perceptual data are mapped into them, behavior is regulated by them. Each person probably possesses a very large stock of such images that can be flexibly recombined with each other.

But for our present purposes we must select from among this wealth a smaller set of images. These are the ones that are deliberately chosen to carry the special message the individual scientist is trying to formulate and convey. They are not simply chosen, but constructed, winnowed out, criticized, and reconstructed. They are the product of hard, imaginative, and reflective work, and in their turn they regulate the future course of that work. The scientist needs them in order to comprehend what is known and to guide the search for what is not yet known. He must represent to himself the possible unknowns. But these representations are not fragmentary bits of speculation. Just as we need organized schemas to represent the world as it is, we need them to represent the world as it might be. The special, empirically testable hypotheses scientists sometimes construct in a seemingly neutral spirit are really sample products of the activity of some organized representation of the world. The movement, from such hypotheses to a conscious delineation of their source-images, marks an important turning point in the growth of any scientific thought process.

Such images lend palpability to otherwise vague ideas. This feature accounts for the ability of images of wide scope to liberate the kind of high excitement that permits prolonged and attentive labor, so evident in scientific work. We most often see this excitement displayed when the thinker focuses attention upon a single great image. This focus gives rise to illusions of monolithicity. We are tempted to look for the one great image that motivates an individual or the members of a discipline, or of an age. Even when we recognize that an intricate theory is formed in the interplay of ideas, there remains a strong tendency to summarize the individual as though there is an allotment of one great image to each great person.

But as I have tried to suggest, not only is there a plurality of images, but this is a necessary condition for fruitful work. Although we do not know anything about how many complex images a person can or ought to work with, a little guesswork may not hurt. If we consider Darwin's image of the tree of nature, we can see that it took many hours of work to fashion and refashion it. It reflected long study of many special taxonomic problems and alternative taxonomic schemes. Meanwhile, in another domain, plant and animal breeding, a great labor was necessary for Darwin to reach the point where he could see the useful analogy between artificial and natural selection. And so on, for each of his enterprises. Useful images of wide scope do not come as cheaply as the ideas thrown out hastily in a brainstorming session (imagine Einstein trying to brainstorm!). Moreover, to use them well—to examine the intricacies of each one, to find new and fruitful combinations of them, to express these ideas understandably—all this takes its toll of time and energy. It would be my guess then that the number of images of wide scope that one individual can bring to bear in one lifetime of scientific work is rather small, something like fifty or one hundred, that is, not one and not many thousands. Perhaps the individual can cope with four to five wide images that serve as leitmotifs for an entire life and a somewhat larger number, say fifty to one hundred, that are used in the elaboration of these thematic organizers. How small this number is can be felt, if not seen, by comparing it with the number of images unselected subjects can produce in a mnemonic processing experiment of the sort I referred to earlier. In one such experiment I found that subjects could produce about one useful pair of "narrow" images every five seconds, a rate of about six-hundred in a fifty-minute hour (Gruber et al. 1965).

The issue of number has a bearing on what we may call the erotic side of scientific work. In some general sense, every scientist may form an emotional cathexis with the whole of nature, or better, with his idea of the whole. But in actual work we see that every person must make severe choices. This is not merely a matter of the time it takes to get the work done or to learn enough to do it. Much of the time goes into forming a deep enough cathexis with some particular set of natural objects or ideas to permit the steady engagement of the person's whole effort. Such love is not formed in an instant. In matters of work the scientist may be polygamous but not promiscuous. Creativity demands commitment.

The need for commitment can be turned around and looked at in another way. One of the functions of complex images is to give the thinker something almost palpable to permit the formation of a productive cathexis. Not only people and animals but ideas can be lovable (or hateful). And just as students of literature tell us that it is not quite the person but our image of him that we love, it may well be that it is not quite the idea or concept that we love but the image from which the idea is formed.

This attachment, with its attendant access to the person's whole value system (which Boulding treats as another set of images), may help to explain an otherwise quite puzzling experience. When we hear of a new idea or a new finding, we often know with a sense of great immediacy that it "feels right" or that it "feels wrong." Only later do we work out our reasons.

I began this discussion by distinguishing two aesthetic moods in science and suggesting that productive scientific work depends on a lively interplay between them. But these two moods each have many features, and we may expect that every individual scientist will have a different aesthetic profile. I have used the examination of Darwin's complex imagery as a vehicle for exploring these two moods. The subject of such imagery remains quite dark, deserves study. Although some images are shared, many are personal. They are so personal that even when the individual displays them openly they may go unnoticed. This is a gloomy picture. Can we only communicate successfully by means of highly simplified sketches of the products of thought? Is the intimacy of sharing thought itself and the feelings that go with it—

these most human of all experiences—is this beyond our reach? Perhaps so. But perhaps we have merely not yet lived in a world where thinking men and women really stop to listen to each other or to take long and loving looks at each other's images. Is this impossible?

# Ensembles of Metaphors in Creative Scientific Thinking

In the recent upsurge of interest and research on metaphor the main emphasis has been on understanding the general nature of metaphor, with much discussion devoted to competing ideas such as the comparison and interaction theories of metaphor. With regard to the use of metaphor in scientific thought, an issue of concern has been the question, is metaphor theory-constitutive, communicative, or emotionally evocative? In literary discussions the actual contents of metaphors used has been explored. But in cognitive science circles the tendency has been to choose metaphors rather arbitrarily to test various special hypotheses about metaphor in general, without undertaking a full examination of the use of metaphors in context (see for example Ortony 1979).

The aim of this essay is to propose a method, the study of ensembles of metaphors, as an avenue for understanding the symbolic function in scientific thought. Naturally, as part of our work we have been interested in the role of metaphors in creative thinking. But we have not followed the path of searching for the single root metaphor lying behind the whole of a person's thought (see Pepper 1966). Instead, we conceive of the creative person as constructing a system of metaphors which, together with the ideas they carry, form a sort of web-like structure, with metaphors at some nodes and abstract ideas at other nodes.

Previous investigators who have looked at collections of metaphors have centered their attention on the metaphors characteristic of a domain of thought or activity, rather than a single person's work (see Gentner and Grudin 1985; Lakoff and Johnson 1980). In line with our emphasis on case studies of creative individuals, we have been examining ensembles of metaphors in Darwin, James, Bergson, Piaget and Freud (see Bruchez-Hall 1986).

## The Evolving Systems Approach to Creative Thinking

We think of a creative person as being composed of three major sub-systems, each of them evolving in its own way, somewhat independently of the others: an organization of knowledge, an organization of purpose, and an organization of affect. When we study the organization of purpose we refer to it by a special term, the *network of enterprise*. This accentuates the fact that the creative person is engaged in more than one important activity at a time and that these take place over long periods of time, sometimes practically the whole working life. For example, Darwin began to study earthworms in 1837 and wrote his book about the subject in 1881. Piaget began his

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scientific career as an adolescent with the study of molluscs and was still working on this enterprise to the end of his long life, actively publishing over many many years. The astonishing thing about most enterprises is their longevity.

When we focus our attention on the network of enterprise we are emphasizing the interplay of the organization of knowledge and the organization of purpose. When we study the idea of ensembles of metaphors, my main subject in the present essay, we are bringing out the interplay of the organization of knowledge with the organization of affect. Unhappily, the discussion of metaphor that has exploded in the last decade or so, has been almost all cognitive; very little attention has been given to the affective.

The general function of creative work is the transformation of experience. Imagine, for example, two pictures each showing the three neighboring mountains, the Eiger, the Mönch and the Jungfrau. In one, very pretty but quite literal, you see a flowered field and the mountains behind them; in the other you see the metaphoric, or symbolic rendition of the same scene with the mountains personified and interpreted as the ogre, the monk and the maiden—a system of untouchables.

The metaphoric transformation of nature can have other consequences, with a different affective tone. Consider *I wandered lonely as a cloud*, a poem by William Wordsworth, and the study of the poem. On April 15th, 1862, this nineteenth century romantic poet went for a walk with his sister, Dorothy Wordsworth, who was his constant companion. They saw a long belt of daffodils bordering a lake. When they came home she wrote down the experience in her diary (Wordsworth, 1798-1803/1973). Sometime later, going through her journal, he discovered the entry that she had made and he wrote his beautiful poem about the daffodils. So we have a transformation of the original sensuous and perceptual experience first into an image, a verbal image captured by Dorothy, and finally into poetic form by William Wordsworth. But there is one more step to mention. The poem is not just a poem about daffodils, it is a poem about the imagination and the pleasures of the imagination. So there is still a further transformation that takes us beyond the realm of the original sensuous experience. This poem was written in 1804, when Wordsworth was thirty-four years old. It is noteworthy that he took up the same theme—in a less flowered and more intellectual form—in a poem written in 1844. Herbert Read has written an interesting commentary of the later poem (Read 1965). So the same sort of transformation of nature, giving it human significance and intellectual quality as well, is present both in the pictures of the three mountains (a different kind of three-mountain problem) and in the story of the poem by Wordsworth.

In keeping with the aims of the *evolving systems approach*, if we are to deal with creative work, we have to sensitize ourselves to the type of process that is non-homeostatic. A great part of life's processes are homeostatic.

When we use the word "adaptation," by and large we mean a system or subsystem so organized that it corrects deviations, always coming back to some preset norm or equilibrium value. But sometimes we have to go beyond where we were, abandon our preset desired values. We have to break out of our own past, grow and create.

Psychology badly needs some understanding of the sort of mechanism—something like positive feed-back systems, multiplier effects, and so on—that would help us to appreciate how an organism that is by and large homeostatic can sometimes go beyond its present state into some new and unpredictable future. The study of metaphor is a promising way of examining that problem. Regardless of different theoretical nuances, there is general agreement among students of metaphor that we are not dealing with a mere comparison of the tenor and the vehicle, of the term to be explained and the term that explains it, only to point out their similarity. Rather, out of this comparison and the interaction of the terms, out of the new combination, something new appears. Some surprise. Sometimes the surprise is in the perfect fitting of the two terms together. Sometimes the surprise comes about the other way, through the mismatch that we detect once having made the metaphor. The construction of a new metaphor is a new combination with creative potential. It is, as it were, one strategy for producing and detecting novelty.

## THE CONCEPT OF METAPHOR

I turn now to a brief examination of the concept of metaphor. In the seminal book edited by Andrew Ortony, *Metaphor and Thought* (1979), it is surprising how little metaphor is defined. Almost every author in the book comes up to the issue of definition and then side-steps it, so that in practice, the usage in the book is a very generous, encompassing definition of metaphor; metaphor, simile, parable, analogy, allegory and various other forms are all treated together as examples of the same sort of thing. In a similarly broad vein, Lakoff and Johnson, in their book *Metaphors we live by* (1980), write: "The essence of metaphor is understanding and experiencing one kind of thing in terms of another." My American Heritage dictionary says:
" ... Metaphor is 1) a figure of speech in which a term is transferred from the object it ordinarily designates to an object it may designate only by implicit comparison or analogy." And then it gives a second definition: "Figurative language, allegory, parable." The basic idea of understanding and experiencing is not present in this dictionary definition. The key term used there is "transferred," whatever that means. And then the definition moves away from comparison or analogy toward allegory or parable.

Of course, Lakoff and Johnson intend a special use of the term metaphor, one which is important for my purposes because it relates to the idea of an ensemble of metaphors. They want to show how one might do a systematic inventory of the metaphors that are, if not universal, at any rate extremely common in a language. Lakoff and Johnson treat metaphors as large groupings that serve as organizers of the concepts that may be expressed by using them. These are metaphors such as container, journey, person or commodity. Their point is that a concept cannot, generally speaking, be well expressed by a single metaphor. For example, love is a journey, love is a story, love is a container, (you put something into it, you get something out of it)—and so you need to use several metaphors to explain or express the one concept.

As discussion advances, it will be important to avoid being so liberal in our definition that everything is metaphor. It probably would be helpful to have a taxonomy not only to define metaphor but to create a lexicon of related terms. To give only one example of something that isn't a metaphor but functions something like one, consider thought experiments such as Einstein's about uniform motion on a train, or about uniform accelerating motion of falling bodies in a free falling elevator. He uses his thought experiments to explore events in something that is not a train in one case and not an elevator in the other. These "experiments" are not metaphoric but something like it. I leave that as a question: how are we going to draw a boundary around metaphor and say, well here is where it stops and here is where thought experiments begin?

It might be added that taxonomies also deal with likenesses, systems of likenesses and unlikeness but they are often very dry, and affectively and aesthetically almost at the opposite pole from metaphor.

## THE FUNCTION OF METAPHOR

Let us turn to the next question, Metaphor as a tool. When we say that it is a tool, we immediately mean that it might have many different functions, just as any tool does. A tool is not just to build this house with. A hammer is to pound with and it can pound in all sorts of ways for all sorts of purposes. Broadly speaking, the cognitive functions of metaphor are to organize knowledge to understand something, to raise questions and to communicate with others. Metaphors also express feelings. Typically, metaphors are laden with some feelings about the cognitive contents involved.

Reorganizing experience includes simply connecting disparate sensuous experiences. For example, not long ago I took my four year-old grandson to a large outdoor sculpture museum in New York. He spied one piece of sculpture immediately on arriving. It is a striking zigzag pillar about twelve meters high (Endless Column by T. Streeter in the Storm King Arts Center, New York State). He looked at it and immediately exclaimed: "Look: a worm!" This assimilation is an example of a small boy pulling together sensuous experiences from different realms and making some larger unit of sense in his world.

Another function of metaphor in science is to serve as a temporary scaffolding to permit the organization of ideas. Then the metaphor can drop away. This is commonly thought to be the main function of metaphor: to use it until you know how to do things better. When you can think more abstractly, more formally, or more literally correctly, you dispense with the metaphor and get on with the real business, especially in scientific work, of saying things non-metaphorically. Although that is not a good general description of how science works, it should be said that there are occasions on which metaphor functions in just that way.

A good example of this temporary scaffolding function is Herbert Simon's (1969) parable of the two watchmakers. I am sure that in his case it was something that helped him to get on with his thinking, and helped him to express the very subtle idea of partially decomposable systems. Once he had told the story he didn't really need it for his own further thinking.

Another function of metaphor is naming things, or concepts. For example, when we say "the arms race," we are using the word metaphorically, as a shorthand that comprises a great deal of meaning into very few words.

Metaphors also facilitate the interaction of different levels of experience such as sensuous experience and abstract images.

Another general function of metaphor is to change our intuitions. Lakoff and Johnson gave good examples of this in their discussion of various metaphors involved in understanding the idea of love or the idea of argument. For example, the idea that "argument is war" is both evoked and supported by the metaphors that express it. But you could imagine a change in the very nature of argument, so that it would no longer make sense to say that argument is war. Suppose, for example, that our present conception of argument was replaced by an image of two people trying to decide together on some truth that neither one alone would have access to, then we would need a new metaphor for "argument." So another function of metaphor, still under the heading of organizing experience, is to change our intuitions by examining concepts in the light of fresh metaphors.[1]

Finally, metaphor can serve as a guide and a spur to analysis. Consider Figure 1. on page 246 and Figure 2. on page 247., Darwin's branching tree of nature. Darwin used and re-worked that conceptual tree over and over to examine his thinking about the process of evolution. At one point, for example, he says: "Tree not good similie. [Instead it would be better to say] Piece of seaweed endlessly branching." What has he in mind? Knowing Darwin's notebooks well enough it is not hard to guess: The tree is anchored in one place and the seaweed is not anchored; the tree has a central trunk, seaweed has not; the branches of a tree get smaller and smaller, seaweed does not.

In another place he says: "The tree of life should perhaps be called the coral of life, [because the] base of branches [is] dead, so that passages cannot be seen." Each time he invents a new variant it is not in order to say that this is the *correct* variant for understanding the branching processes of nature, but to say: here is a feature that was not captured in my previous metaphors. I need one more metaphor in order to say this about my irregularly branching tree of nature. Used in this way, the construction of metaphor becomes a tool for analyzing concepts.

Since there are, as we have seen, a number of different possible functions for metaphor, there is no reason to think that all thinkers use metaphor in the same way or to the same extent. We have to be cautious in making generalizations about creative people, because the one thing we know about them is that each one of them is unique, by

1. The aim of our current research on the cooperative synthesis of points of view (metaphor of the shadow box) is to change our intuitions about argument.

definition. We don't want to surrender the hope of developing reasonable and precise models of how individuals function. But we don't need to suppose that the model for one person will be the same as the model for another. This point applies to the use of metaphor as much as it does to any other aspect of creative functioning.

## METAPHOR AND CONTEXT

Generally speaking among psychologists and philosophers, but not among literary folk, metaphor is discussed in the singular and with a capital M: What is Metaphor? What is Metaphor really? Examples are chosen here and there to suit particular theoretical purposes as though the essence of metaphor can be captured in a singular key example, or two essences can be captured in two key examples. That's true of the book edited by Ortony, which is both an influential book and a good expression of the state of the art, at least as it was a few years ago. In his introduction, Ortony promises that the second half of the book will be devoted to how metaphors work in text, in a context, in a live protocol. But, I think it is fair to say, that never happens in the book.

In the quest for simplicity, which is the hallmark of the experimental method, many investigators of metaphor have reduced the stimulus material to the barest minimum. In a nominative metaphor, for example, the minimum is three components: noun phrase, copula, noun phrase—as in "surgeons are butchers" (taken from Camac and Glucksberg 1984).

In this minimal form, as a number of investigators suggest, it is tempting to argue that the essence of metaphor lies in the conceptual similarity of tenor and vehicle. Moreover, in a number of studies, conceptual similarity has been taken to mean prior association of the terms (Johnson and Malgady 1979). Camac and Glucksberg point out one of the failings of this "prior association hypothesis," namely that it ignores the different functions of tenor and vehicle. Conceptual similarity of two terms is not affected by their order, but the metaphor "my surgeon is a butcher" is quite different from "my butcher is a surgeon." The underlying context that makes both of these metaphors comprehensible is probably a set of occupational norms: in one case the metaphor means that the surgeon is below the norm for surgeons; in the other case that the butcher is above the norm for butchers; and that the norm for surgeons is in some ill-defined way higher than the norm for butchers. Thus the order effect depends on an implicit context. In the same article Camac and Glucksberg also point out that quantifiers should have no effect on conceptual similarity, but that they do have an effect on the meaning and plausibility of metaphors. Thus, "some psychologists are torturers" seems more plausible than the unquantified version, "Psychologists are torturers." (Likewise for "generals are murderers"?)

McCabe (1983) has shown that if context is reduced to a bare minimum, conceptual similarity is an influential variable in determining the effectiveness of metaphors. When they were given isolated metaphors to rate, her subjects considered those metaphors good that were independently judged to have high conceptual similarity. But when the same metaphors were presented as part of more extensive texts, there was zero relation between similarity and rated metaphoric quality. Moreover, there was no correlation between ratings of metaphoric goodness of the same metaphors in and out of context.

McCabe's examination of the conceptual similarity hypothesis was especially thorough in that she used three kinds of material: metaphors composed for purposes of the experiment, metaphors selected from ordinary discourse, and metaphors selected from published fiction. In all three cases the conceptual similarity hypothesis was confirmed for metaphors taken out of context and disconfirmed for metaphors in context.

If meaning and comprehension of metaphor are highly sensitive to context effects, it seems plausible that the same would apply to the construction of metaphor. There is little research on this whole subject, but Pitts, Smith, and Pollio (1982) have suggested that the very process of making metaphors changes as a function of the type of larger task within which it is embedded.

It is remarkable that so many experimental investigators have been drawn to finding ways of studying metaphor without ever asking their subjects what the metaphors in question mean. In my explorations of this subject it has become apparent that a given metaphor generates a field of possible meanings, and that there are wide individual differences in the actual meanings constructed by different subjects. This fact lends weight to the argument that we must look at metaphors in their context.

## ENSEMBLES OF METAPHORS

By and large, among psychologists and philosophers the issue of groups or ensembles or families of metaphors has not been addressed very much. There are a few exceptions. Steven Pepper's book, *World hypotheses* (1966), generates a list of key metaphors. It's a very short list, four or five key metaphors. Holton's book *Thematic origins of scientific thought* (1973) does something similar although he arrives at a list of about a hundred fundamental themes. Lakoff and Johnson produced an inventory of common metaphors. They do not actually produce a full-scale inventory but just enough of one, in the form of reflections on the process of making such an inventory, to suggest how, if carried on for another ten years or so, that process would produce the official inventory of metaphors in the English language. Something similar is true of a recent, very interesting paper by Gentner and Grudin (1985) on the development of metaphors in almost one hundred years of psychological writing. Their method involves a very severe sampling technique that gives them a corpus of metaphors small enough to be manageable and yet possibly, they suggest, almost exhaustive of the metaphors of their time. I am a little sceptical about that claim but the important point is that they are not talking about the metaphors in one person's head. Far from it, they are talking about the metaphors accessible within a discipline, a discipline evolving over a period of some ninety years.

The relationships among metaphors and ideas may be depicted as a web, with metaphors at some nodes and concepts at others. Each concept may be connected to or supported by several metaphors, and each metaphor may be linked to several concepts. The same kind of web diagram might apply to the metaphoric structure of a culture, a discipline, or a single person's thought. Our aim is to study a creative person at work, and to use the notion of an ensemble of metaphors, or the related idea of a field of meaning, as a way of describing a particular person at work. Even in the most limited case there is a fairly large, extended web of relationships among metaphors and concepts.

How large? Is there some limit on the extent of such webs so that we might say: this represents one ensemble and now we will start over again with another one? Or is there just one large, everbranching, never ending network? That may be an important question, but there is no clear theoretical or empirical basis for answering it now. In practice, we have taken as the unit of analysis the ensemble of metaphors pertaining to one project or one enterprise. Thus, in the Darwin case I have treated the metaphors Darwin used in constructing the theory of evolution through natural selection as one ensemble. Osowski (1989) has treated the metaphors William James used in writing *Principles of Psychology* as an ensemble. In each case, the project in question represented an important sector of the person's work, but by no means the whole of it.

### *Charles Darwin's Ensembles of Metaphors*

To illustrate the idea, let us now examine one ensemble of metaphors, the one used by Darwin in constructing his theory of evolution.

There are few thinkers in the history of science who have received anything like the attention given to Darwin. He is an accessible writer. Undoubtedly, if there is one key idea associated with the name of Charles Darwin, it is natural selection, or evolution through natural selection.

With some authors there is a danger that our interpretation will impose a metaphorical label where the author's intent was quite literal. Darwin, however, was quite explicit about his metaphorical intent. He writes, for example:

> I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. (Darwin 1859, 62)

In a similarly metaphorical mood, in an earlier sketch of his theory, he described the process of selection as the work of "a being infinitely more sagacious than man (not an omniscient creator)" (Darwin 1909, 6). His image of nature was a personification of an intelligent being that selects (similar to Maxwell's thermodynamic Demon of a few years later). In spite of some controversy, it seems to be widely agreed now that selection is in fact a metaphor, as Darwin uses the term (see Young 1985; Hyman 1962).

Let us consider two groups of metaphors that Darwin used. On the one side, natural selection, artificial selection (the way in which Darwin eventually came to use the resemblance between natural selection and plant and animal breeding, as an experimental analog of a natural process), and finally the metaphor of war, the war of nature. That is one group of metaphors; they are all on the side of triage; they all have something to do with "selection," with "death," with "elimination" of part of what was there before.

On the other side, you have another set of metaphors, centered around Darwin's image of the irregularly branching tree of life meant to capture the idea of the explosive differentiation of nature as new variations arise and new species are formed. Oddly however, in Darwin's celebrated moment of insight on reading Malthus on September 28, 1839, the metaphors he uses do not include the tree. The tree metaphor had risen to prominence in his thinking fifteen months before the idea of natural selection. But at the moment of having the idea of natural selection, he uses the wedge metaphor to express approximately the same idea. (See *Darwin's Tree of Nature and Other Images of Wide Scope*, 241).

The wedge metaphor and the tree metaphor both deal with the proliferation of variety in nature, the expansiveness, the richness of nature. But Darwin also believed that there is some number of species that must remain approximately constant, that nature cannot just keep on differentiating. Consequently coupled with this explosive variation, there must be some selection, some 'triage', some reduction of the number in order to maintain an approximate constancy in the number of species in nature.

The metaphor of the tangled bank appears in several places, most prominently in the eloquent final Paragraph of *On the Origin of Species*. Darwin asks us to imagine a tangled bank where the many different species are all interacting with each other, tumbling over each other, eating each other, fertilizing each other, and so on. In this tangled bank the "Struggle for Life" goes on, and from the implacable war of nature arises the beauty and the harmony of the natural order. The tangled bank captures the richness of nature at a moment in time, the tree metaphor captures the constant enrichment of nature over time.

The metaphors Darwin used in constructing this theory may be divided into three grand classes: those dealing with enrichment and growth; those dealing with selection or triage; and those dealing with adaptation—nature's "contrivances."

What we need in order to understand Darwin's theory of evolution through natural selection is not a partisan view that one metaphor is better than another, but some idea that the different processes, to which the metaphors apply, have to interact with each other, and have to come to some kind of balance. Unfortunately, among social scientists in particular, attention has been given almost entirely to the metaphors of "triage." Very little attention has been given to the other two kinds, expressing the productivity and the ingenuity of nature. Just as this imbalance gives a very poor view of Darwin's thinking, it impoverishes our own thinking about nature, about living organisms.

*William James' Ensembles of Metaphors*

Because of his richness of style and content, and his strategic place in the history of psychology, James is an interesting subject. The metaphors he used in constructing *Principles of Psychology* have been analyzed by Osowski (1989). The metaphors of his later philosophical work have been examined by Gilmore (1971). Cornesse (1933) has given a more general account of James' imagery. In spite of the similarity of their topics, the overlap among these three dissertations is almost zero. This fact gives some idea of the richness and complexity of the metaphorical structure of thought in a creative person.

Osowski's work is particularly useful in drawing attention to the organization of ensembles of metaphors into clusters, or "families." Each family is comprised of a number of terms that are all used more or less interchangeably to bring out somewhat different aspects of the same idea (e.g. stream, chain, and train—among James' metaphors for continuity of mental life). These clusters are part of the larger ensemble of metaphors, in which they cannot be interchanged with other clusters (e.g. James' use of the herdsman metaphor for the idea of directedness in mental life is distinct from the stream-continuity family).

*Jean Piaget's Ensembles of Metaphors*

Work on the metaphorical structure of Piaget's thought has only just begun. It might seem that this will be a difficult and perhaps unrewarding task, since his writings are to a large extent abstract, formal, and non-figurative. But there is no need for us to expect that all creative thinkers are alike in their use of metaphor. And we may find that there are certain key points where metaphoric analysis is particularly useful. Moreover, not all of Piaget's writing has the same character. Consider the following passage from *The Psychology of Intelligence*. "In fact every relation between a living being and its environment has this particular characteristic: the former, instead of submitting passively to the latter, modifies it by imposing on it a certain structure of its own. It is in this way that, physiologically, the organism absorbs substances and changes them into something compatible with its own substance. Now, psychologically, the same is true, except that the modifications with which it is then concerned are no longer of a physico-chemical order, but entirely functional, and are determined by movement, perception or the interplay of real or potential actions, (conceptual operations, etc.). Mental assimilation is thus the incorporation of objects into patterns of behavior ..." (Piaget 1950b, 7-8).

As this digestive example suggests, it may not be extremely difficult to work out the metaphorical structure of Piaget's thinking, perhaps no more difficult than, say, in the case of Darwin. It takes work and from what we know about James, it may take as many as three to five doctoral dissertations (using a dissertation as a unit of intellectual progress—one hopes) really to exhaust the metaphorical structure of an important thinker's ideas.

## SOME PROBLEMS FOR FURTHER WORK

To conclude, I will discuss some of the limitations and problems of present research on metaphor.

First, the aesthetic side of making and comprehending metaphors is given little attention. Sternberg, Tourangeau, and Nigro (1979) have at least advanced a theory specifying a distinction between what makes metaphors comprehensible and what makes them pleasing. But surely there ought to be more to aesthetics than pleasingness.

Second, the study of metaphor, when it is done searchingly and honestly, reveals a great deal of intersubjective variability in the meaning people read into a given metaphor. Nevertheless, we do manage to communicate reasonably well, some of the time. How does the context in which a metaphor appears reduce its ambiguity? Does it? If we undertake to contextualize the study of metaphor, is it not imperative to take up vigorously the issue of ensembles of metaphors, and the fields of meaning they generate?

Third, if ensembles of metaphors are to become an important focus of attention, that will exact the time, patience, and concern for the individual subject necessary to really understand how this set of metaphors works in this person's thinking.

Fourth, a problem of method. At what "grain" of analysis should we tackle the study of an ensemble of metaphors? If we really search for every metaphor in a text or protocol, we run the risk of listing almost every word in the language. In the approach my collaborators and I have taken, we have looked for metaphors at about the level of the paragraph or chapter. This can lead to ensembles containing something like five to one hundred different metaphors, and that is, for the present, complexity enough. But this approach does neglect the level of the word and sentence, that is, the level at which we can say that someone's speech is colorful or flat, precise or suggestive, terse or abundant, etc.

Fifth, we need to improve the way we go about describing the growth of a person's structure of ideas and purposes, and their relation to the growth of his ensembles of metaphors.

Sixth, we need to begin work on the problem of transitions between one level of experience and expression and another. For example, in an interesting essay, *Imagery in Scientific Thought* (1984), Miller makes a good case for the importance of imagery and intuition in the growth of modern physics. In order to do so, he must argue for the emergence of a "new mode of visualizability" (p. 256). In this effort, Miller, a theoretical physicist and historian of science, can get a little help from psychologists so far as finding categories or modalities of experience. But so far as understanding the all important transitions from one mode of thought to another, modern psychological enquiry has little to offer.

Finally, in our efforts to be scientific and empirically objective, we may work too hard at enumerating the many metaphors that are made more or less explicit by the subject. This might prevent us from undertaking the difficult interpretative task of asking: what does this thinking person really intend by everything that he is doing? Guided by that question, we may find some metaphors that are not so much detectable in the text as between the line in the text as a whole. In such matters we could surely take lessons from Freud, who knew how to work over one text at many levels, and from Borges, who could construct a meaning that was not present in the part only in the whole.

To be sure, such quasi-literary aspirations create the danger that we may be distracted from the quest for objectivity that is the hallmark of science. Nevertheless, our task is not to reduce symbolic meaning to the level at which we can study it, but to develop methods for studying it as it occurs in genuine creative thought processes. As David Krech once said, it is easier to tame a wild idea than to have one.

# The Life Space of a Scientist: The Visionary Function and Other Aspects of Jean Piaget's Thinking

In earlier times (i.e., the turn of the century), the study of creativity meant, more than anything else, the study of imagery. More recently, however, problem solving has taken first place as almost synonymous with creative thinking. Indeed, *Productive Thinking* (1945), the seminal work of the Gestalt psychology founder Max Wertheimer, might equally aptly have been called either *Creative Thinking* or *Problem Solving*. Wertheimer's protégé, Karl Duncker (1945), did in fact title his classic and still seminal monograph *On Problem Solving*. Newell and Simon's (1972) monumental work is *Human Problem Solving*. Although problem solving looms large in the scientific enterprise, it does not stand alone. Other activities —including problem finding, making metaphors, absorbing knowledge produced by others, collaborating, disseminating and so on—all play their roles.

In this article I draw attention to relations between creative scientific work and our knowledge of varieties of phenomenal experience. I focus on still relatively neglected facets of scientific work: the visionary function, ensembles of metaphor, insight and understanding, a high level of aspiration, and the joy of discovery. Without these, the scientific enterprise would be impossible. As I have recently written elsewhere, the motivational and social aspects of creative work remain to be systematically explored (Gruber 1998c).

In spite of many qualifications, few will deny that major features of the scientific enterprise involve constructing or discovering some sensible relation between evidence and theory. The scientist must produce appropriate transformations in both directions, moving between sensuous experience and conceptual thought. For this reason, I advance the idea that there is a kind of "experiential space" in which the creative scientist can move around and come to navigate coherently, searching for correspondences, isomorphisms, complementarities, pathways, and stable structures—in short, all sorts of relations of fitness or appropriateness. In examining scientific work, too, one end product is words. Both before and after all is done—in the form of experiment, systematic observation, equations, and diagrams—something must be said. This is why metaphor is so important: Lying somewhere in the middle of the visionary spectrum, it serves as a bridge between conceptual thought and sensuous experience.

By the *visionary function*, I mean a wide spectrum of types of experience ranging from perception to conception. These experiences must form some sensible relation with one another if intellectual life is to be coherent and even possible. These various

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"takes" on the world can communicate with and modify each other. There is no privileged sequence or direction of these interactions.

In addition to looking at each of these separable aspects of the experiential space, we must also consider them together, both in their interactions and mutual influences and in the ways in which they complement each other. Up to the present, they have usually been the province of investigators working in different disciplines and on vastly different timescales. It is now necessary to bring these disciplines to bear in a more integrated way on the study of creative scientific work.

The enterprise of science is primarily cognitive in nature. It has to do with how we know the real world, how we make discoveries, how we understand. Insofar as it originates new knowledge, it is a prime example of the creative process. But we should not forget that science also has social, aesthetic, emotional, and moral aspects.

I turn now to my main subject, the study of scientific creators at work. A great deal of psychology focuses either on species-typical or average performance of a prototypical human being, or on what Jean Piaget called the *epistemic subject*. But a full-blooded psychology requires knowledge of the atypical subject, the optimal performer—humanity at its best. This presents new challenges, both conceptual and methodological. Among other things, it is necessary to accumulate a fund of the kind of knowledge that can best be gotten by detailed, intensive case studies. This is not yet a mainstream activity, even among devoted students of creativity. In moving in that direction, we should not be afraid of criticism for avoiding generalizations from the extraordinary to Everyperson, or vice versa.

Creative work is so complex that its students often simplify their approach. This leads to cycles of emergence and disappearance of research fashions. One year, problem solving is the hot topic; the next, it's divergent thinking. Then metaphor gets its turn. Then intrinsic motivation. Then we follow the flag to social influences, mentors, merchants, power brokers, prizes, and other extrinsic motivations. Meanwhile, in another whirlpool, we may circle from primary processes to cognitive science, from purposefulness to chance, from steady work to sudden insights. Some of these movements are sheer faddism; others are important manifestations of natural rhythms in the movement of thought. For example, on oscillations between atomism and holism, see Pledge's interesting book, *Science Since 1500* (1939).

If, in this article, I focus on some aspects of the creative process, I do not mean to deny the importance of others or of the knowing system as a whole. In this article, I (a) sketch briefly some systemic aspects of creative work as part of the rationale for the use of the case study method, (b) outline a spectrum of processes that can be grouped as the visionary function, which includes metaphor and other figures of thought, and (c) illustrate the previous points by examining both Piaget's creative work and his ideas about creative work, drawing on unpublished interviews and other sources.

## THE EVOLVING SYSTEMS APPROACH

We can characterize the creative person as a complex evolving system composed of three main subsystems—organizations of knowledge, purpose, and affect. We take these to be only loosely coupled with each other. What happens in one part of the whole conditions and shapes the rest, but not deterministically: Each part has also a life of its own. The net result of this loose coupling leads to our sense of the inherent indeterminacy, or freedom, of creative work.

The development of responses to music provide a good example of loose coupling. When we first hear Beethoven's Ninth Symphony, we may be stirred to our souls. On subsequent hearings, our knowledge of the piece increases, probably up to some limit. Meanwhile, our emotional reactions also change, but in their own ways, waxing and waning according to various circumstances not entirely related to our cognitive awareness of the piece. These two streams of experience, then, are only loosely coupled. The same might be said of a scientist's reactions to a just-hatched scientific discovery. Humphrey (1992) recently wrote an interesting discussion of the relations between different streams of experience.

This notion of loose coupling applies also to the relation of the individual with society. The fact that creative people, like everyone else, are social beings, part of a social system, does not strip them of their freedom and individuality.

The emphasis on complexity, system, and loose coupling motivates the importance we give to the case study method. Of course, there is often value in isolating one or another facet of the whole for intense scrutiny, and here experimental methods are indispensable. But it is the special responsibility of the student of creative work to always strive to reestablish and maintain a view of the system functioning as a whole. In this regard, I particularly like a remark by Wittgenstein in his essay, *On Certainty*: "When we first begin to believe anything, what we believe is not a single proposition, it is a whole system of propositions. (Light dawns gradually over the whole)" (Wittgenstein 1969, 21). But in order for that to happen, one must at least try to examine the whole. Above all, we should not get so involved in our specialized branches of knowledge that they become black holes from which no light can ever escape.

One very general finding from examining creative lives in some detail goes well under the name of *pluralism*. There is not one great X—a variable or trait—that characterizes or explains the creative person or creative process; there are many such facets. Taken together, these express the functioning, the continuous functioning, of the creative system. Thus, there is not one great insight, but many such moments—one of which may or may not turn out to be among a few of the crucial ones. Also, there is not one great mentor, but interlocking circles of social relations, with a few mentoring relationships appearing and disappearing in the course of time. Thus too, there is not one central motive, but a number of them forming a system that governs the conduct of the creative person. Part of this motivational system, the creator's organization of purpose, I have dubbed the *network of enterprise*.

And thus too, there is not one great image or ruling metaphor at work, but whole sets of them, which I call *ensembles of metaphor*. Of course, *ensemble* is the French word for "together." But in both French and English it means more—a unit or group of complementary parts that contribute to a single effect. Thus, inevitably, the fitting of part to part leads back to the concern for properties of the developing whole.

## THE VISIONARY FUNCTION

By and large, we do not, in our research on creators' evolving systems, ask why the person is creative, but rather, how does he or she do the work? To elaborate on a systemic approach to creative work, it is of the utmost importance to explore the mutual relations among the different sorts of phenomena that enter in. Otherwise, every new discovery may simply burden us with an increase in bewilderment at the complexity of it all.

I use the term *visionary function* to capture the interconnectedness of phenomenal experience at different levels, and indeed, of experience and action. I use the term to get beyond the literally visual and quasi-visual of much imagery research. Remember, we call Saint Joan a visionary because she heard voices. The voices she heard were those of Saint Michael, Saint Catherine, and Saint Margaret—none of whom she had ever seen in the flesh, nor heard nor touched. When the Reverend Martin Luther King Jr. said "I have a dream," he was speaking of a world he had never known in reality.

Thus the choice of the word *visionary* is itself a metaphor. There is more to be seen than one sees with the "eye of the body." There is also what Darwin called the *eye of reason*. There is a spectrum of quasi-perceptual phenomena. Our language reflects something important they all have in common: Regarding each of these phenomena, we are liable to say "I see," meaning "I understand," or "I hear you." Moreover, when we say "I see" in this sense, we intend a certain immediacy of experience. Furthermore, each of these phenomena plays a special role in creative thought. Near one extreme, that closest to actual perception, we have afterimages—brief continuations of direct perceptual processes. Next we have icons and echoes—short-term memory images that last long enough for information to be read off of them. Next we have images of the kind that are usually intended when we speak of imagery—a kind of long-term recall of things once actually perceived, as in Galton's (1883) pioneering "breakfast table" questionnaire, or as in "imageless thought."

We come next to a kind of abstract imagery, what Miller (1984) called *Anschaulichkeit*. In Miller's account, much of early twentieth-century physics labored under the conviction that certain fundamental physical ideas were nonvisualizable, and that imagery could play no role in modern physical thought. But in a development climaxed by the invention of Feynman diagrams, the existence of a type of abstract imagery became clear—diagrammatic conceptions of things that are in principle not perceptible, but can be diagrammed or schematized in an intuitively direct manner, hence *Anschaulichkeit*. It should be noted that these visualizations are not necessarily visual images. A person with primarily kinesthetic imagery, for example, might create such a visualization at the blackboard, or speak an illuminating sentence.

Finally in this spectrum there are the mental events we have in mind when we use the term "visionary." Imaginings of states of the world, or of society remote in space and time, fall into this category—as do general philosophical beliefs that are not directly testable by ordinary scientific inquiry but that nevertheless guide certain forms of thought. Utopian thought is an example of such idealizations; and in physical thought, there are perfect vacuums and frictionless machines, states of affairs that can never exist in reality but are essential for rational thought.

By "visionary function as a whole" then, I mean not one or other of the regions of this spectrum, but the whole gamut taken together—and not merely as a set of types, or a unidirectional order of dominance, or a deterministic sequence—but as a space of possibilities in which manifold relations and transformations can be explored. Or, as Wittgenstein put it:

> Think of chemical investigations. Lavoisier makes experiments with substances in his laboratory and now he concludes that this and that takes place when there is burning. He does not say that it might happen otherwise another time. He has got hold of a definite world-picture—not of course one that he invented; he learned it as a child. I say world-picture and not hypothesis, because it is the matter-of-course foundation for his research and as such also goes unmentioned. (Wittgenstein 1969, 24)

The place of metaphor in this experiential spectrum is elusive, for it is both a part of the spectrum and a tool for capturing relations within it. Some metaphors have an everyday content and others reach for abstractions. Spurgeon (1935), in her classic work, *Shakespeare's Imagery*, found that Shakespeare had many images of everyday life, but also quite a few that reached for the stars.

My contention is that metaphors can best be understood as part of the visionary function, as tools for the transformation of experience from level to level. At one extreme is direct perceptual experience, at the other, various kinds of abstract imagery. For convenience, I begin the discussion closer to one end than the other, but that is not an assertion of priority either of the perceptual or the conceptual end. In short, metaphors and ensembles of metaphor are an integral part of working systems of beliefs.

Among the simplifications I have committed in proposing this spectrum of types of experience is the summary treatment of ordinary kinds of perception, knowledge, belief, and expectancy that arise from inspecting the world and acting in it. Not only do these forms of experience influence each other; in important cases they resist such influence. For survival, we must see the tiger in the brush whether we expect the tiger or not. Such relations between perception, belief, and knowledge have been studied in the experimental laboratory (e.g., see Gruber and Dinnerstein 1965), but little connection has been made between such work and studies of scientific creativity.

As for the moral aspect of science, bear in mind there are several kinds of morality: religious morality, justice morality (as studied by Kohlberg 1984; Piaget 1932), the morality of caring (as studied by Gilligan 1982), planetary morality (Carson 1954, is an emblematic figure here), and truth morality (as examined by Asch 1952; Campbell 1990). Insofar as science is guided by moral considerations, it is primarily truth morality that is at stake in scientific work. But the other kinds come into play too, the overall profile differing between persons, between cultures, and between historical periods and circumstances. It would be naive to ignore the fact that there are no perfect moral beings; nevertheless, moral codes and exemplars carry weight, have force. In our own era perhaps we see emerging a serious concern for planetary morality. Scientists among others will be giving increasing attention to such matters. Later in this article, I return to the relation between science and values in Piaget's thinking.

*A Historical Note*

As behaviorism declined, interest in imagery and other cognitive functions rose. When imagery began to come into its own, there was some recognition of this spectrum of phenomena, of the isomorphisms and transformations going on between image and metaphor, for example. But a narrowing and fragmentation soon set in. When Miller, Galanter, and Pribram (self-styled "subjective behaviorists") wrote their influential book, *Plans and the Structure of Behavior* (1960), they began with a poetic image of the world taken from *The Image*, a book by the economist Boulding (1956). This represented a promise to deal with both image and plan. But there is far more about plan than about image in the rest of the book. Moreover, Miller et al. were very clear about their concept of image: "The image is all the accumulated, organized knowledge that the organism has about itself and its world" (p. 17). That is neither phenomenally nor cognitively the same as the usual use of the term, as in "mental imagery." Later, imagery research bounced back but in a narrowed form—more amenable to experimentation—so that by far the greater part of contemporary imagery research is restricted to phenomena close to the literal perception end of the spectrum, such as the imagined rotation of a visual image of a cube.

The development of imagery research is an important advance. Nevertheless, if pursued in isolation it will not achieve the integration we need for understanding creative scientific work, the grasp of the visionary spectrum as a functional whole.

There is a wealth of evidence of all sorts of connections among different parts of this spectrum. Our knowledge of false memories shows that an experience once imagined can become as psychologically real as something actually seen and remembered (Loftus 1993). The classic Perky (1910) experiment showed how a percept could be mistaken for an image. One sometimes fails to distinguish between a book read and a film seen; the elements of the two versions fuse. Piaget cited an example of this type from his own life and reports related findings in research on the development of children's imagery (Piaget, Inhelder, and Sinclair de Zwart 1973). It should be noted that for the most part these interactions are probably adaptive and useful, as when audition and vision cooperate in making another's speech more audible.

A recent elegant study by Shepard and Cooper (1992), supported by an independent study by Izmailov and Sokolov (1992), shows that the color circle, Red-Orange-Yellow-Green-Blue-Violet-and back to Red, is found both at a perceptual level and at a semantic level. It would be strange indeed if a magnificent edifice such as human language was not well adapted for truthfully representing isomorphisms and other relations among different realms of experience.

It is widely agreed, or at least supposed, that levels of experience remote from direct sensuous experience are by that token flexible and well suited to the needs of creative thought. Indeed, Richards (1936) warned against assuming too tight a relation between literal visual imagery and metaphor. While it would be hard to imagine the world of metaphor without roots in sensuous experience, these two different parts of the experiential spectrum should not be identified or fused with each other just because they have some formal and semantic similarities.

## ENSEMBLES OF METAPHOR

I use the term *metaphor* broadly to cover images, similes, metaphors, thought experiments, and other figures of thought. This usage is not unlike a recommendation by Richards (1936); Spurgeon (1935); the poet Nemerov (1978), when he spoke of figures of thought; or Danziger (1990), when he wrote of metaphorical schemata and metaphorical systems.

One illustration shows how broad the meaning of metaphor can be. You see moving vans all over Athens emblazoned with the word *Metaphor*. There the word means "to transfer," just as we use it to mean "to transfer a meaning from one thing to another."

A telling case in point—Locke's (1965) ensemble of metaphors for the acquisition of knowledge—shows the need to consider the ensemble of a thinker's metaphors, rather than each in isolation. Nothing could be more familiar to psychologists than Locke's image of the tabula rasa, the blank tablet on which experience inscribes knowledge—standing for the passivity of the knower before the inscribing world. And yet, as a description of Locke's thinking, this is at best a half truth. The *Essay Concerning Human Understanding* (1965) opens with an entirely different metaphor: The knower is a hunter after ideas; he sends his trusty falcon out into the world, and the bird brings back new knowledge. Of course, discoveries made on the wing must be classified and organized—these active processes are captured in another metaphor, the "commonplace book," which is both a real notebook and scrapbook combined, as well as a metaphor for organizing activities of mind. Locke wrote extensively on how to organize and index such a record of experience. The word *commonplace* did not mean ordinary, it meant "common place." Aristotle used a similar term for the place where you put together things that go together, as in the act of classification. Put more generally, all of Locke's metaphors, including the tabula rasa, are related to his political philosophy—his questioning of the divine right of kings. Knowledge, Locke (1965) insisted, is not handed down from monarch to monarch, not handed down at all—but hard won through active search and experience in the world.

In scrutinizing an ensemble of metaphors, then, it is crucial to ask how does this metaphor work in this particular belief system? Merely categorizing metaphors and other figures of thought by form or by content is not enough. For example, there are many cases involving light as a metaphor for creativity, but they have very different meanings, as in the following.

*Lightning as Metaphor for Creativity*

Sudden insight is a bolt of lightning striking the creator. The new idea comes all at once, it happens to the person, and it is a rare or singular event. I have discussed elsewhere (Gruber and Davis 1988) how erroneous a description of real lightning this suggests, but that does not concern us here.

Lightning is used in an entirely different sense by Wordsworth (1979) in an early version of his autobiographic poem, *The Prelude*. Here lightning is "gentle," touching the poet and shaping his destiny, rather than striking him with an idea Wordsworth made it clear that he is that person:

> The mind of man is fashioned and built up
> even as a strain of music. I believe
> That there are spirits which, when they would form
> A favored being, from his very dawn
> Of infancy do open out the clouds
> As at the touch of lightning, seeking him
> With gentle visitation—quiet powers,
> Retired, and seldom recognized, yet kind ... (p. 3)

Lightning appears in Shelley's (Shelley n.d.) preface to *Prometheus Unbound*, a classic poem of revolt: Prometheus against Jupiter. No wonder the rebel Shelley can write of lightning as emanating from within the poet's mind.

> The great writers of our own age are, we have reason to suppose, the companions and forerunners of some unimagined change in our social condition, or the opinions that cement it. The cloud of mind is discharging its collected lightning and the equilibrium between institutions and opinions is now restoring, or is about to be restored. (p. 227)

Light is used in a different sense in the quotation from Wittgenstein (1969): "Light dawns gradually over the whole." Light and fire appear as key images of creation and creativity in the Bible, in Blake's poetry, in Shelley's—but the sense of each metaphor must be worked out in each case, from its place in a system of beliefs and feelings.

## ENSEMBLES OF METAPHOR IN AN INDIVIDUAL'S THOUGHT

Let us examine the ensemble of metaphors that occur not in a discipline (as in Leary's (1990) *Metaphors in the History of Psychology*) and not in a language taken as a whole (as in the work of Lakoff and Johnson 1980) but in the formation of a system in an "individual." We soon come on one very primitive question: How many metaphors make an ensemble?

Treatments of ensembles of metaphors choose, if you will, very different degrees of magnification. This results in very different counts of the numbers to be considered. At one extreme, you have the idea that there is one great metaphor. Pepper's (1966) influential book, *World Hypotheses*, speaks of four great organizing metaphors—formism, mechanism, contextualism, and organicism. But he insists that to be a good and coherent thinker you should be guided by only one of these and avoid making a mess of things by conflating them all. So Pepper's basic metaphor number is one or, at most, four.

Merton (1965), in *On the Shoulders of Giants*, discussed the history of one metaphor—Newton's phrase, "If I have seen further it is because I stood on the shoulders of giants." Gould (1987), in *Time's Arrow, Time's Cycle*, liked dichotomies, two metaphors at a time—linear time and circular time. To be fair, in the way metaphors interact, other metaphors arise. But he is aiming at a very small number, one or two.

At the other extreme, and there are really very few examples like that in Spurgeon's (1935) book, referred to earlier. She found more than 6,000 metaphors in all of Shakespeare's plays. She used the word metaphor in a very extended sense, as I do here. She found about ten metaphors per page in Shakespeare's work.

Somewhere in between those two extremes, my own numbers range from about five to twenty. In my essay *Darwin's Images of Wide Scope*, focusing especially on his image of the irregularly branching tree of nature, I found five or six metaphors or families of metaphors (Gruber 1978a). My student Osowski (1989), in his study of William James's metaphors in the celebrated chapter on the stream of thought, came up with a similar number. These are the metaphors at work—not in the life as a whole, but in a single project. Osowski used an interesting concept: to think of metaphors as forming a kind of spider's web, with metaphors at some nodes and concepts at other nodes. Another student, Powell (1980), previously used this idea in an unpublished study of Elizabeth Bishop's poetry. We have become more and more aware of the difficulty of separating metaphors and concepts from each other in such a clear way, but I think we can still retain the idea of sensuous experience, metaphors and concepts working together to form a belief system.

In Leary's *Metaphors in the History of Psychology* (1990), there is only one chapter, by Smith (1990), in which ensembles of metaphor "within a person" are dealt with. Smith examined three behaviorists—Hull, Skinner, and Tolman. There is a certain deliberate irony in his choosing to study the leading behaviorists' metaphors, since obviously many behaviorists might think of metaphor as an illegitimate category, too mentalistic for scientific analysis. For Tolman (1932), the metaphors given are of maps, mazes, webs, and rats—the rat being a metaphor for man. We are reminded that Tolman's book, *Purposive Behavior in Animals and Men* (1932), closes with a poem ending "the ratiocinations of my amazed mind." Tolman really loved metaphor.

## THE VISIONARY FUNCTION IN PIAGET'S THINKING

In the present discussion I do not distinguish metaphors from other figures of thought. Mainly, I list and comment on some of Piaget's most prominent metaphors. Ideally, one would show how a particular set of figures of thought helped the creator to develop and express new ideas, and explicitly, how the set of figures may be fitted together with each other to knit the web of thought either in one individual or in one communicating group.

In examining ensembles of metaphors we probably should not expect to find permanent groupings, but only provisional working partnerships. Metaphors and other figures of thought are opportunistic, both in how and when they are constructed, and in how and when they are used. Perhaps thinking can be likened to a set of textured screens moving across each other so that different Moiré patterns are constantly appearing. The set of screens representing figures of thought lies somewhere in the middle, mediating between perception and conception.

In applying this line of thought about the visionary function to one individual, Piaget, I draw on examples from published works and from a series of discussions I had with him in 1969. First, I explain the setting in which these nine interviews took place[1]. When I first went to Geneva in 1955 or 1956, I was quite ignorant about Piaget's work, and was drawn there by a not very profound curiosity, I began to work to try to understand Piaget's method and system. Many of my observations and knowledge of Piaget's thinking come from long contact and participation in his group in Geneva, along with some walks and talks, hikes, and even a few dinners with Piaget and his family. One year I attended his university lectures, sometimes meeting him beforehand for an early morning coffee. Not to be forgotten is my immersion in Piaget's work necessary to produce *The Essential Piaget* (1977).

1. My nine tape-recorded interviews with Piaget took place in the summer of 1969 in the study in his house in Pinchat, a suburb of Geneva. All interviews were in French. All translations were made by H. Gruber and checked by a native French speaker and former student at the University of Geneva, Dr. Chantal Bruchez-Hall.

The nine tape-recorded interviews mentioned above were understood by both of us to be part of an attempt to study the creative person, Piaget, at work. We had an understanding that we would try to avoid expositions of Piaget's ideas that could be found in many books. Of course, that wasn't entirely feasible, but throughout these interviews—partly through my questions but also through his very eager cooperation—we did maintain a distinct focus on the creative process. The interviews all took place in his supremely messy study. One balanced their drink precariously on one pile of papers, and the tape recorder somewhere else.

*Piaget's Network of Enterprise*

The intellectual setting can be seen from a very brief sketch of Piaget's network of enterprise—what Piaget was doing in the recent past—which we can take as indicative of what was on his mind at that time. In 1956 he had formed the *International Center for Genetic Epistemology*, which became for several decades a constant feature of the Geneva scene. In 1967 he published *Biology and Knowledge: An Essay on the Relations Between Organic Regulations and Cognitive Processes* (1971) and in 1968, the little book *Structuralism* (1970b). All three of these efforts can be thought of as reflecting Piaget's underlying systems of metaphors. The very existence of an interdisciplinary group that would meet throughout the year and have special symposia at the climax of each year was an expression of Piaget's idea of the "circle of the sciences," first expressed in his novel, *Recherche* (1918c), when he was twenty-two. This key figure of thought expresses the view that no single science is a stable intellectual whole, because each makes assumptions that it cannot justify; however, the presuppositions of one science are the warranted results of a neighboring field. Consequently, arranged and properly fitted in a ring structure, the body of scientific knowledge taken as a whole stands firm.

It should be noted that both Piaget's imaginary circle of the sciences and his real network of enterprise are at once intensely social and uniquely individual. There are collaborators, mentors, borrowers, and so on. Prevalent domains of effort give shape to his work. At the same time, there is Piaget in his study, on his walks alone—all part of the creator's role in constructing the world in which he works.

*Growth* and *nutrition*, and the catchwords *assimilation* and *accommodation*, were especially prominent figures in Piaget's classic monographs about his own babies. These ideas, however, run all through Piaget's work.

*Biology and Knowledge* (1971) contains one large set of metaphors in which Piaget tried to show the relations between biological and knowledge-getting processes. These are two-sided metaphors. Sometimes he was illuminating biology by looking at the mind, other times the reverse. With regard to *Structuralism* (1970b), anyone trying to find structures common to very different fields of knowledge is engaging in a very abstract kind of behavior. With a little generosity of spirit, we might call Piaget's work here *metaphorizing*.

While he was doing all of that work over the decade or so preceding these interviews, he also published three volumes on what he called "the figurative functions of thought," in collaboration with Inhelder and others—*The Mechanisms of Perception* (1969), *Mental Imagery in the Child: A Study of Imaginal Representation* (1971b), and *Memory and Intelligence* (1973). These volumes can be seen as dealing with parts of the visionary function. On the one hand, they describe the materials that must be transformed to construct the nature and stages of what Piaget called intelligence. On the other hand, their development demonstrates the way operatory intelligence comes to dominate and guide figurative thought. Finally, starting in about 1958, he had undertaken what was to become a prolonged reprise of his early work on causality (Piaget 1972).

### *Toys as Metaphors*

Underlying much of Piaget's work were two metaphors, one very general and applying to all of his experimental work, the other specific to causality. Giving the child something to fool around with—an object, a gadget, something to draw, something to make—had become, for Piaget, "a way of thinking." In observing the child, he and his collaborators deliberately created occasions to reflect on the relations between processes going on in the child and other processes that may have taken place in the history of science or elsewhere in the whole gamut of epistemological enquiry.

In that sense Piaget always behaved as though the stuff of these experiments were metaphors. The metaphor of toys is closely related to an important metaphoric idea that runs through Piaget's entire career, the two-sided metaphor of child as scientist, scientist as child. To study either one is to illuminate the other.

### *Projection*

With regard to causality, Piaget was driving toward the idea that the understanding of causality is itself a projection. Adults have some conception of mental operations. When you have a causal experience, when you "see" something causal in the world out there, you are attributing those mental operations to the objects and events under consideration. Thus it is a process of projection, not in the psychoanalytic sense but in other respects: an internal event projected onto the world out there.

### *Piaget's Self-Referential Metaphors*

Metaphor hunting is a subtle task. It is interesting to consider several that are more or less explicitly self-referential. They are, in effect, Piaget talking about himself. The first one I recount comes from an unpublished interview by Eleanor Duckworth (personal communication, 1973):

> Piaget had been on a train in a compartment with an Englishman, an elderly gentleman, who had very deep crow's feet. Piaget couldn't tell if the man was smiling or not. Because of the crow's feet "he looked like he was smiling all the time. I just couldn't tell." End of story on the train.
> A few days later, Piaget says, "I caught myself smiling in a way that was quite unusual for me. I could not see myself, but I could tell that I was smiling in a way that was unusual for me. So I tried to figure out what I was doing: I was imitating my Englishman. But I did the imitation before I had the image. And then I said to myself: 'That's it! Consciousness was made possible by the act of imitation.'"

Consciousness here should really be read as the "grasp of consciousness" (la prise de conscience). It requires an act—it doesn't just happen free, at no cost or effort. To make it happen you have to do something. This was not a new thought for Piaget. But the story does give some indication of the reflective way he went about in his world.

Piaget was a lusty man. He liked living, walking, and eating. During most of the years that I knew him his wining and dining were restricted. But he liked the things of the world, the sights and sounds. He loved music and we talked a lot about his listening to music, about his having a private concert given to him by Segovia. He reflected on what was going on, and for this he drew not only on his scientific work but also on his personal experience. This habit of active reflection was as natural for him as avoiding reflection is for many people.

### *Exploring les Possibles: An Implicit Metaphor*

Now I come to an implicit metaphor from our first interview. I call it implicit because all Piaget did was to describe his behavior, and I am the one who is labeling it a metaphor. But this does not require a great conceptual leap.

Piaget was describing his annual pattern of work. His twenty to thirty collaborators had all been a part of the Center for Genetic Epistemology symposium, composed of research reports by the local collaborators and reflections by an international team of savants from several disciplines. There were not many collaborators from the social sciences. They came mainly from physical sciences, mathematics, and philosophy. In the final session of the week-long symposium, Piaget announced the topic for the next year—such as contradiction, causality, or les possibles—and asked people to find ways to embody it in experimental concretizations.

Then, at the first meetings in the fall, Piaget came with twenty to thirty ideas of his own; the assistants and other collaborators supplied another twenty, in other words one or two apiece. The difference was probably not simply that Piaget was inherently more prolific than the others, but rather that he worked harder at it, collected ideas from other people, and after all, knew better than anyone else what he was driving at. Most important of all, perhaps, was that the central idea for each year's work usually had a much longer gestation period for Piaget than for the others.

This process reminds one of divergent thinking, doesn't it? But Piaget detested the idea of fortuitous accidents and random outputs governing the growth and process of thought. He had another way of thinking about the same thing. He later mounted a whole series of experiments to study how children explored the possibles in their world, or in some experimental microcosm (Piaget 1987). But he considered this to be "systematic scanning," not random trial and error. He said the same thing about the mental *possibles* as he said of biological mutations. The latter are the emergent product of the genome—the entire genetic makeup of the individual as it already stands—transformed into a process for exploring what might next evolve. He also had some quite specific, pioneering notions about the (then excluded as impossible but now accepted) possibility of reverse transcription—from RNA to DNA—by which this internal process of genomic exploration could be triggered and guided.

*Incubation*

The next metaphor to be considered was also implicit in Piaget's behavior. The term *incubation* has been used to refer to unconscious or involuntary continuations of conscious purposeful thinking either during periods of rest or of preoccupation with other matters.

Piaget said: "When I have done a number of chapters I leave them for six months in a drawer, to reread later. One then senses what is missing, what must be developed or shortened" (Interview, 1969). I don't know whether there was a real drawer, or whether it was a more strictly metaphorical drawer of the mind. In the French language, to put something in a drawer does mean to put it away for a while. So much for long-term incubation.

Short-term incubation was what happened within a day's work. Piaget got up in the morning, started to work; things got muddy, and he went for a short walk for about half an hour. He came back and things were clearer to him. He repeated the same process after lunch, but the walk was longer. Again, things were clarified. On these walks, he said, "I don't think much, but when I come back the ideas are clear. It's not a conscious process" (Interview, 1969). In support of this self-description, it is clear from Piaget's behavior that he did not avoid company on these walks, and he could carry on discussions about various subjects without fearing that his train of thought was being unduly interrupted.

Examining the incubation metaphor as it functions in a life history setting brings out an important question. The timescale of incubation processes that Piaget described fell into two vastly different categories: put the work in a drawer for six months, or just go for a walk. In either case, he made it explicit that he was not consciously thinking about the suspended work during the time in question. For the shorter periods, the point may have been that he was just resting. For the longer periods, the key point may have been that he had occupied himself with other tasks.

*Writing as Thinking, Internal Logic, and Composing Music*

Now we come to tandem metaphors, metaphors that work together. In this case there are three: writing as thinking, internal logic, and writing as composing music. For Piaget, ideas did not become fully conscious, if they existed at all, unless he wrote.

"One procedure that I use a lot is always to stop the day's work in the middle of a phrase. If my ideas are not very clear I prefer to begin then stop, and then it completes itself the next day, almost immediately" (Interview, 1969). So we have an echo here of the Zeigarnik effect, the spontaneous tendency to take up and complete interrupted tasks (see Lewin 1935). But this was more than the laboratory phenomenon. This was the purposeful person managing his own system of motives by intentionally creating an interruption.

I asked him if he ever had insights while moving around, the way both Poincaré and Kekulé described—Poincaré put his foot on the step of the bus and bingo! Piaget (Interview, 1969) said, "No, it is while writing. As soon as I have a few pages done there is an internal logic (another metaphor) that imposes itself." As we continued this discussion I asked if, at the beginning of the day, he had a definite plan. "No that comes as I proceed, like a melody that continues itself." He used that melody metaphor several times.

*Music*

Music is much more than melody. In our conversations in the summer of 1969, he used musical metaphors more than once. I believe he was more prone to draw on larger symphonic structures than melodic line. In *La Mission de l'Idee* (1916), written when he was nineteen (see below), he wrote that in the divine symphony, "humanity is not a mere sum of individuals, it is the greater whole which goes beyond and coordinates the multiple resonances" (translated in Gruber and Vonèche 1977).

*Morality and Structure*

This metaphor arose as Piaget's (Interview, 1969) very spontaneous response to my question, which had to with the source of his projects, and whether he had the time to do everything. His reply was that he could always find resources for anything that interested him.

> Someone suggested the book on moral judgment, which was a little beyond what I was doing [which was the study of certain logical functions]. But that attracted me because moral judgment is not [a matter of] feelings; it was the

> aspect of logical structure that I hoped to find in a domain quite different from simple knowledge. I put two or three years into that, but it was not really a foreign direction. It was a parallel to make with intelligence. (Interview, 1969)

*Adolescent Dreamer*

When we discussed the idea of work, Piaget (Interview, 1969) said:

> The adult works. The child does not work. Work is the coordination of actions with a goal, for a long period. While the child has momentary goals ... What you call "to have a goal" for the creative mind is when it succeeds in coordinating all these partial goals in a system. But almost all adolescents do that, partially. Adolescents, when they begin to give their lives a goal, they all have ideas of grandeur which are quasi paranoid—n'est-ce pas? [He speaks of the continuum from such adolescents to adult creators.] ... I am convinced that every creative mind has its goals in adolescence. Not clearly, but the direction.

I am not sure about the empirical generalization that Piaget was making, but he was certainly describing himself very well. (On adolescents, see especially Inhelder and Piaget 1955). Piaget's prose poem, *La Mission de l'Idée* written when he was nineteen years old, is one enormous sixty-five-page idea of grandeur. Although it is not wonderful poetry, it is very grand, and you can even be moved by it. It shows an adolescent well begun in the developmental task of finding meanings in the world. The medium of poetry is particularly well suited for the transformations between sensuous experience and abstract thought that express the visionary function at work.

## PIAGET AND POETRY

Ascent or climbing is an appropriate metaphor for creative growth, especially for a Swiss youth beginning his scientific career collecting snails amidst the grandeur of the Alps. The theme of "ever higher" appears in various places in Piaget's writings.

In Piaget's prose poem, *La Mission de l'Idée* this theme arises repeatedly. In one verse he wrote: "Sometimes, the great ascent which humanity pursues generation after generation seems to halt." In another verse he wrote of the upward movement of life through biological and social evolution. In still another, he told the story of two boys lost in the forest. One panics and runs unthinkingly into the woods and is lost. The other climbs a tree, finds the lay of the land, comes down, prays, and goes safely home. In the closing verse he wrote of a future:

> When the idea is reborn, every man now suffering in the shadows will find his place in the vast harmony which by its crescendo will make life grow so high that it will see God.
> The scientist, who finds hypotheses, must build over them a grand edifice that can contain them. (Gruber and Vonèche 1977, 37)

Recently, Vidal (1994) rediscovered two sonnets that Piaget published in 1918. One of them, *Première neige*, describes an austere snowscape. The other, *Je voudrais*, is a love poem in which the youth leads his beloved to a high place where they will "soar above the human horizon" ("*au-dessus de l'horizon humain*") (Piaget 1918b, 155).

How fitting is this metaphor of ascent for a man whose leitmotif was to become the search for understanding of *équilibration majorante*—ascending equilibrium!

The older Piaget was not very poetic. To be sure, the visionary function was very much in evidence in his thinking, but his figures of thought were not framed as poetic metaphors with intensely imagistic or poetic metaphoricity. And that's a surprise, or it ought to be, on two counts. First, I believe that he was a very sensuously responsive human being. Second, he had published poetry as an adolescent, followed by a novel—thus demonstrating an early strong interest in the very kind of transformations that I have been discussing as the visionary function. Of course, it was a philosophical novel, very abstract—but still, it was a novel of adolescence, full of *Sturm und Drang*. Also, as a mature man his talks did have a certain amount of irony, humor, and imagery. My sense of anomaly and surprise may stem from our chronic separation of cognition and affect. For Piaget there was no contradiction between rhapsodic joy on one hand, and very abstract thought on the other.

Thus, we can say that Piaget was metaphorically rich in the sense that for him, these formalizations that he spent so much energy on were systems of metaphors, and the interdisciplinary relations that went to the heart of his thinking indeed expressed a system of metaphors. This examination of Piaget's metaphors within the larger context of his life and work brings out the way that they drew on his network of enterprises—on the fact that he was involved in biological, philosophical, historical, sociological, and various kinds of psychological work. He had a very complex network and frequently drew on one part of it to support or enrich another. This process of cross-fertilization depends directly on the making of metaphors and on the visionary function as a whole.

This point is brought out by considering the modalities of Piaget's thought, which were predominantly verbal and symbolic. "Je ne suis pas du tout visuel," he said, more than once. The lack of visual imagery was reflected in his behavior—an almost complete absence of pictures or diagrams in his works, which were mainly a mighty river of words.

At the same time, Piaget obviously had important, indispensable visual experiences. You cannot imagine most of the clinical interviews, especially those done from 1930 on, without the child looking at some material and Piaget looking at the child in action. Or especially later in his life, Piaget listening to his collaborators describe their observations of children, thus bringing yet another step into this series of transformations. In some instances, the central point was the child's visual experience, as abstracted and understood by the investigator—as in Piaget's studies of perspective taking. In other cases, conflict between knowledge and visual experience became the central point—as in Piaget's studies of the child's ideas about conservation of matter, or as in some of his experiments on contradiction.

So, if Piaget lacked visual imagery, it does not mean that he lacked either visual experience or the ability to transform it into the play of abstract ideas that were the main modality of his thought.

It is important to specify here that the spectrum of experience that I have been discussing describes best the Piaget of his everyday life—Piaget the would-be genetic epistemologist and developmental cognitive scientist. He confessed (Schepeler 1993) that in another context—the psychoanalysis he underwent in his late 20s—he had very vivid and powerful visual images, some of them of childhood experience. This distinction illustrates the functioning of the cognitive system as it is situated within an internal psychological milieu, embedded in turn in an external milieu. Together these reflect the thinker's affective life and social relations, as well as his or her cognitive achievements.

### *Insight and Joy in Piaget's Thinking*

If there is a certain surprise value in Wertheimer's (1945) use of many stages rather than one great *Gestalt switch* to describe Einstein's thought (see also Miller 1975), it might also come as a surprise that Piaget, the great exponent of slow, protracted intellectual growth, experienced moments of insight and sometimes described children in those terms too. Piaget was aware of his kinship with the Gestalt psychologists, but also went to some lengths to clarify the distinction between his approach and theirs.

A good example of this dialogue between related approaches was Piaget's discussion of the distinction between the fifth stage of infant development, *discovery of new means through active experimentation*, and the sixth stage, *invention of new means through mental combinations* (Piaget 1952c, 263-341). He wrote:

> The sudden inventions characteristic of the sixth stage are in reality the product of a long evolution of schemata and not only of an internal maturation of perceptive structures ... This is revealed by the existence of a fifth stage, characterized by experimental groping ... What does this mean if not that the practice of actual experience is necessary in order to acquire the practice of mental experience and that invention does not arise entirely preformed despite appearances? (Piaget 1952c, 382-383)

The "inventions" Piaget had in mind here were, when looked at from an adult point of view, very modest indeed—such as grasping the idea that to insert a pencil in a certain hole one may have to reverse it because it is the pointed, rather than the blunt end that must enter the hole.

> [Jacqueline, age one year eight months, has been having difficulty inserting the point of a pencil in a hole if her father, Piaget, hands it to her with the blunt end toward the hole.] At about the thirteenth attempt, Jacqueline suddenly changes methods. She turns the second pencil over ... and no longer tries a single time to put it in by the wrong end ... one has the impression of a sudden understanding, as of an idea which arises and which, when it has suddenly appeared, definitively imposes itself. (Piaget 1952c, 340)

Piaget's key point was that if one had not seen, or if one disregarded the long series of earlier groupings, the sudden insight appeared to have come from nowhere. Saying this does not detract from the importance of the sudden insight, but it does put it in a different context—the evolving schema of a pencil. We might add to this that numberless such small steps are indeed lost through the incompleteness of most experimental studies, contributing to the error of telescoping narratives of insight based on old memories (see Gruber 1995b). But here it is the investigator of creative work doing the telescoping, rather than the creator compressing his or her own past.

In the course of our interviews, I asked Piaget about his own experiences of insight. He said, as I have related above, that they came to him "while writing." Notice that he is not describing a moment of sharp insight or solution of a problem, just a clarification. Wittgenstein's (1969) remark, "light dawns gradually over the whole," seems to fit very well here. From many encounters, I would certainly say that Piaget took pleasure in such occasions, but I don't imagine him running like Archimedes, naked in the streets, or even doing a little jig.

However, Piaget (Interview, 1969) did describe one grander moment. The most beautiful moment in his life, he said, was when he discovered a group of 256 transformations of certain logical structures. He described rhapsodically the joy he felt as he worked this out during a fourteen-day ocean crossing to Brazil. "It was wonderful: the open air, the sea breezes, but always the calculations, no temptations!" (Interview, 1969). Notice that this "moment" of insight lasted about two weeks.

What comes of this joyful work? The driest stuff that anybody ever wrote ... even Piaget. Table after table of nothing but logical symbols, filling page after page. But for him these tables of symbols had a deep significance (Piaget 1952b). The rhapsodic feeling as part of his own thought processes was fully foreshadowed in the figure of Sebastien, the protagonist (i.e., himself) of Piaget's (1918c) novel of adolescence, *Recherche*.

On the whole, Piaget was more interested in the growth of the child's understanding than in the child's problem solving. Of course, observing the child solve problems is one important window to its understanding. But actually observing and analyzing the process of problem solving is a relatively recent interest in Geneva, exemplified especially in the work of Inhelder and her group (Inhelder et al. 1992; Leiser and Gillièron 1990) on procedures.

In Piaget's description of children's thinking, the affect most in evidence is interest and curiosity. But in at least one case that he often recounted there is a suggestion of joyful triumph. A child, the son of a mathematician friend, was absorbed in arranging and rearranging a collection of blocks in different configurations, and then counting them each time—straight line, circle, square, and so on. Each time the number came out the same. Finally the child cried out, "Once you know you know forever!"

## CONCLUSION

In drawing to a conclusion it is instructive to look at a distinguished physical scientist who has been as explicit as he could be about the fabric of experience that one weaves in doing science. Roald Hoffmann—renowned chemist who is also an accomplished poet and seriously interested in music, the graphic arts, and in the psychology of creative thinking—illustrated the process of mining the diversity of experience for creative ends. In the article, *How Should Chemists Think?* (1993), he described the process of synthesis of organic molecules and compounds, entailing the fitting together of several levels of analysis and, sometimes, several different ways of thought. To describe one chemical synthesis (a long series of planned transformations), Hoffmann used chemical equations, two-dimensional stick figures that show certain chemical relations well, three-dimensional ball-and-stick models, and words. Words were used in at least two senses—(a) as needed to give a specific and literal description of the complex molecules in question and (b) metaphorically to give a larger sense of the whole process. In another "case study" (as Hoffmann called it), he recounted the synthesis of a beautiful molecule, the ferric wheel. Of course, its visual beauty is not immediately apparent but requires x-ray diffraction and the construction of a model that reveals it.

Hoffmann (1993) mulled over the musical analogy most fitting to capture the particular beauty of the ferric wheel:

> For me, this molecule provides a spiritual high akin to hearing a Haydn piano trio I like ... Why is this molecule beautiful? Because its symmetry reaches directly into the soul. It plays a note on a Platonic ideal. Perhaps I should have compared it to Judy Collins singing *Amazing Grace* rather than the Haydn trio. The melodic lines of the trio indeed sing, but the piece works its effect through counterpoint, the tools of complexity. The ferric wheel is pure melody. (p. 70)

Finally, Hoffmann made a remark instructive for students of sudden insight. Some syntheses occur in long series of transformations, others seem to happen all at once. In the latter case, it seems as though "the product essentially self-assembles to its final glory. When I see such a process, much more typical of inorganic systems than organic ones, I immediately wonder what I'm missing" (Hoffmann 1993, 70). Hoffmann went on to say that ferric wheels "don't really self-assemble in one fell swoop. It remains for us to learn in the future how those bridges and irons come together" (p. 71).

Why is cognitive growth likely to be composed of a series of relatively small steps? Why—even when the goal is very grand, as after all does sometimes happen—is the path toward it divisible into Poincaré's seven episodes, Einstein's eight steps, and the like?

Imagine if one's thinking underwent a radical transformation every twenty-four hours or every week. Life would be painfully chaotic, the sense of personal identity and of personal connection with one's ideas would be lost. So if insights are to be relatively frequent, they must be of a sort and must occur at such a rate that they can be assimilated into existing mental structures without totally destroying them. Piaget's idea of *assimilation* and *accommodation* applies well here. Life is and must be continuous; cognitive life, too. Like the moving vans of Athens, metaphor is a vessel that facilitates continuity by carrying many meanings: cognitive, purposive, affective, and operative. But to accomplish the necessary transformations between concrete evidence and conceptual thought, the whole visionary spectrum must be freely exploited.

Some cognitive changes do feel bigger than others. Even if the path followed consisted of small steps—the attainment of numerous partial and subgoals—there must be a few last steps by means of which one enters the goal region (Henle 1956). The creative worker must and does have some feel for the importance of the task at hand. And some creators deliberately set high—almost unattainable?—goals. A high level of aspiration, high stakes, high hopes: Do they lead to the heights of happiness? Why not? Not permanently though, for an insight that closes one chapter opens the next one.

We need to account for the seeming disproportion that sometimes exists between the affect felt and the achievement it reflects. One might reasonably suppose that in the legend of Hiero's crown, Archimedes's joy far exceeded the importance of his discovery. But that way of looking at things neglects the transformation of the cognitive field that takes place when the creator is totally engrossed in a problem: Nothing else exists. A step taken is only "small" when seen from outside, by a viewer not similarly engrossed (see Köhler 1971). The historian or psychologist has a different perspective than the discoverer. It is our task to situate the creator in a world. For the creator, that may be a world well lost. Even though it may feel that way to the creator in the toils, in fact, the "lost" world is there but has become background to the problem that is newly figural.

# Chapter 5

# Tracking the Ordinary Course of Development

## *Piagetian Reflections*

Work in creativity is inherently multi-disciplinary, and my own contribution, even before I began to look specifically at creative processes and creative people at work, touches on a number of subdisciplines of psychology. Though the work my colleagues and I have pursued bears on diverse fields such as cognition, personality, social interaction, motivation or education, it cannot be assigned unequivocally to a single one of them. Obviously, this is a factor in work on development as well.

Developmental psychology, however, plays an exceptional role in our work in several respects. First, the *evolving systems approach* to creative work is developmental in its orientation toward long-term changes of knowledge systems. Second, my own network of enterprise is interwoven with that of a man who is regarded as one of the founding fathers of developmental psychology as a research field in its own right, namely with the creative life of Jean Piaget. Our approach to the creative person benefits from a conceptual and methodological kinship with Piaget's research in child development. But there is a deeper sense in which Piaget has inspired our inquiries. Piaget was an outstanding colleague as well as an outstanding case for studying creative work. A significant portion of my career was spent in Geneva exploring this extraordinary thinker—and his work—at work.

In 1955, when I visited Geneva for the first time, I gave a presentation on cognitive gap-filling behavior in perception. The main motivation for this ten-day research trip was curiosity. I had begun studying long-lasting cognitive processes in my case study of Darwin and I was interested in learning more about Piaget's methods of investigating long-term cognitive development in children. When I returned to the United States, I continued to explore Piaget's work in a seminar Walter Emmerich and I gave together at the University of Colorado.

In 1966, though deeply immersed in my work on Darwin, I accepted an invitation to do research at the *Centre International d'Epistémologie Génétique* in Geneva for one year. I was not among Piaget's closest collaborators, yet by participating in classes, seminars and colloquia, I was able to explore first-hand the intensive Genevan research. Besides keeping up with the work on Darwin, I conducted experiments on children's biological thinking, on seriation and classification.

Eight years later, in 1974, I returned to the Centre for another year to undertake a project for which I had been recruited by Piaget. The outcome of this project was that Jacques Vonèche and I put together *The Essential Piaget* (1977), an anthology of Piaget's writings with extensive editorial comment and explanation. *The Essential Piaget*, the introduction to which is included in this section, was not intended as a mere text compilation with introductory purpose. Its aim was to provide a comprehensive picture of the enterprises Piaget pursued throughout his life, a kind of case study in action which would give the reader access not just to Piaget's products, but to his processes as well. As such, it is key to our work on creativity.

The articles included in this section clearly reflect both the power and limitations of Piaget. *The Development of Object Permanence in the Cat* is obviously a study conducted in the spirit of genetic epistemology, as is evident from the adoption of the Piagetian method to examine object permanence. But the other selections highlight our own divergence from Piaget, which can at least partly be traced back to differences in topic: While Piaget treated the epistemic subject by studying the development of thinking in children, our work is concerned with extraordinary individuals—those who deviate from the epistemic norm—, their development as well as their creative activity. It is obvious that these should not be equated carelessly: The end-state of children's development is set externally and historically. In the usual course of cognitive development, the difference between a child's thinking and that of the adults encountered in the environment lessens progressively. The sociocultural setting can thus have regulative functions. The unilinear Piagetian developmental model may be attributable to the externality of regulative mechanisms.

But in the case of creative activity, the cultural environment cannot provide direction, or even account for it. The creative person at work necessarily enlarges the distance between self and surroundings by relentlessly pursuing that which is not yet. The individual him- or herself must guide his or her own creative development. Developmental influences such as mentors, schooling, or a wide variety of experiences may play crucial roles; but the fact remains that no previously constructed route is available to the creative person at work. When we look at these individuals we glimpse the outline of a very different course of development, one that is personal, idiosyncratic, unpredictable, mutable.

# The Development of Object Permanence in the Cat[1]

*together with Joan S. Girgus and Ali Banuazizi*

According to Piaget, the notion of object permanence refers to the psychological fact that an object exists in a continuous time and space; that, despite its disappearance from view in a variety of circumstances, it can easily be recovered; and that, when recovered, it will be the same object in all its physical attributes as when it disappeared. Piaget has demonstrated that appropriate responses to various visual transformations (different kinds of disappearance) of an object develop in children and that they develop along a continuum that is roughly determined by the logical complexity or spatial intricacy of the transformation. For example, in the child's development, following the trajectory of a falling object precedes uncovering an object that has been covered while the child is watching, which in turn precedes uncovering an object that has been covered during a distraction (Piaget 1954).

Piaget's work left something to be desired, since it was based only on his observations of his own three children. Recently, however, Gouin-Décarie (1965) has developed a standardized version of Piaget's methods and applied it to ninety children, ranging in age from three to twenty months. Her findings concerning object permanence confirm Piaget's descriptions in all essentials.

It seems reasonable to argue that all organisms, and most certainly all land animals, must maneuver in a world of objects that have the property of permanence. There are several types of readily recognizable behaviors which would seem to be predicated upon object permanence. These include search, pursuit, detour, and resuming orientation toward an object after distraction.

Thus, it seems reasonable to try to compare Piaget's findings with children with the behavior of an animal living in a world that is similar with respect to object permanence. The cat would seem particularly interesting in this regard since it devotes a great deal of its energy to the pursuit of objects, objects which have the possibility of vanishing from view.

The aim of the present study was to examine the development of behaviors related to object permanence in the cat.

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1. This research was conducted at the Graduate Faculty, New School for Social Research, when the authors were at that institution. The authors thank Colin Beer, Daniel Lehrman, Jay S. Rosenblatt. and Ethel Tobach for their helpful comments on an earlier draft of this article.

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## METHOD

### *Subjects*

Three experimental groups were composed of laboratory-raised kittens and cats: Group 1, 4 kittens, aged 10-12 weeks; Group 2, 4 cats, 24-26 weeks old; and Group 3, 4 cats, 108-110 weeks old. A fourth experimental group, Group 4, consisted of 7 house-reared kittens 10-13 weeks old. In addition, longitudinal data were gathered from 3 house-reared littermates between the ages of 6 days and 10 weeks, and from a second litter of 4 house-reared littermates between the ages of 13 weeks and 30 weeks. All subjects were alley cats.

### *Apparatus*

The test material consisted of 2 soft, cloth objects, approximately 1 x 2 x 1/4 inches, 2 pieces of white cloth, several pieces of string, and a stool 18 inches high.

### *Procedure*

The following test situations were modeled on those used by Piaget in *The Construction of Reality in the Child* (1954).

*Test 1*. A distinct auditory click was made 10 inches to the left side of the animal. This test was repeated with the stimulus to the right side of the animal.

*Test 2*. The experimenter swung a soft, cloth object on the end of an 18-inch thread in a full circle in the horizontal plane about the stationary animal keeping the object about 6 inches above the floor.

*Test 3*. The experimenter placed a small soft, cloth object in front of the animal and moved it initially to attract the animal's attention.

*Test 4*. The animal was placed on a stool 11 inches high. The experimenter placed a soft, cloth object on the stool in front of the kitten and moved it back and forth until the animal started to play with it.

*Test 5*. The animal was induced to play with a soft, cloth object. As he was playing, a distinct click was made 10 inches to the right side of him. This test was repeated with the click to the left side of the animal.

*Test 6*. The animal was induced to play with a soft, cloth object. As he was playing, the experimenter diverted his attention from this object by moving a long piece of string in front of him and off to one side. Then the string was withdrawn.

*Test 7*. The animal was induced to play with a soft, cloth object. As he was playing, his attention was diverted from this object by moving a long string in front of him and slightly off to one side. While he was attending to the string, the experimenter covered the object with a white cloth. Then the string was withdrawn.

*Test 8*. The animal was induced to play with a soft, cloth object. While he was playing, the experimenter covered the object with a white cloth, as smoothly and rapidly as possible, to minimize the distraction of the animal by the movement of the cloth.

With the youngest kittens, testing was discontinued if the subject did not respond positively in Tests 1, 2, and 3. With kittens from the age of around 4-5 to 13 weeks the tests were given in the order listed, in sessions lasting from 30 to 45 minutes, including rests between tests. As they matured (i.e., after 13 weeks), however, it became difficult to hold their attention for the entire series of tests, so the order was varied and tests selected to make certain to test the animals for those behaviors that had not previously appeared in the behavior repertoire.

## RESULTS

During the experimental sessions an attempt was made to record all behavior. In pilot studies, a code was developed to facilitate the notation of the most common behaviors to be described. The code was intended to cover all behavior related to the test stimuli. If unusual responses occurred, they were noted on the protocol. No disagreements arose between 2 independent observers in coding the behavior of 4 cats on all 8 tests. The results are summarized in Table 1. Groups 2 and 3 have been combined, since there were no differences in their responses.

*Test 1: Click*

Every animal in each experimental group immediately turned its head in the direction of the auditory stimulus. In the 3 kittens followed longitudinally from 6 days after birth, this response appeared between 4 and 5 weeks of age. The response changed with age from an extremely global one to a focused, articulated one. The young kitten's first response consisted of a head and shoulder turn; over a period of about 4 weeks this gradually develops into a simple head turn and then into a mere cocking of an ear in the direction of the click.

*Test 2: Object Swung in Circular Orbit*

3 different kinds of responses must be distinguished. (a) The kitten followed the object with his head and eyes as long as it remained within his visual field (i.e., for about 180 degrees); as the object disappeared behind him, he continued to look in the direction in which it was last seen until it reappeared as it came around the circle. Usually, on seeing it again, the kitten exhibited a marked startle response. (b) The kitten followed the object with his whole body, sometimes on his hind legs, circling around at the same speed as the object. (c) The kitten followed the object with head and eyes until it disappeared, then turned in the opposite direction as though anticipating the reappearance of the object on the other side. Only this last response clearly implies a continuous behavioral space in which objects can exist independent of action.

Both Patterns (a) and (b) made their appearance from about 5 weeks on. No kitten younger than 13 weeks ever displayed Pattern (c). In the litter studied longitudinally from 13 weeks on, Pattern (a) began to appear between 13 and 14 weeks in 3 of the 4 kittens, with head turns of approximately 90 degrees.

*Test 3: Object Moved in Front of Cat*

From about the age of 5 weeks on, all kittens played with the cloth object for periods ranging from 15 seconds to several minutes. The animals in the older longitudinal group would play with it for periods up to 15 minutes. Occasionally, the kitten stopped batting the object, looked at it for a few seconds, and resumed playing with it; this sometimes occurred as many as 10 times in succession.

*Test 4: Cat on Stool*

All animals tested knocked the object off the stool onto the floor. None of the lab-reared 10-12-week-old kittens jumped down off the stool in pursuit and resumed play with the object, although all of these animals could easily be induced to jump down by simply moving an object back and forth on the floor within the kitten's visual field. On the other hand, all the kittens in the 10-13-week-old house-reared group immediately jumped off the stool after knocking the object down, and resumed playing with it. This response was also found in the 2 older lab-reared groups. In the kittens followed longitudinally, this behavior appeared at about 7-8 weeks.

*Test 5: Auditory Distraction during Play with Object*

The results of this test were very similar to those of Test 4. All of the 10-13-week-old house-reared kittens and the 2 older groups of lab-reared cats turned their heads in the direction of the auditory stimulus and then returned directly to playing with the object. None of the 10-12-week-old lab-reared kittens showed this return after distraction. In the longitudinally studied kittens, this response first appeared at 10 weeks. Kittens failing to return to the object with which they were playing simply wandered off and did other things that kittens do.

*Test 6: Visual Distraction during Play with Object*

All of the animals were distracted by the moving string. None of the 10-12-week-old lab-reared kittens returned immediately to playing with the first object; 6 out of 7 of the 10-13-week-old house-reared kittens did do so. In the kittens followed longitudinally, this return after distraction first appeared at 9 weeks.

*Test 7: Visual Distraction during Play with Object; Object Concealed during Distraction*

None of the animals resisted the distraction, nor did any return to play with the object and, on finding it covered, search for it successfully. Of the house-reared animals tested at 10-13 weeks, 2 turned toward the covered object and pawed briefly at the white clods, but without uncovering the object. All of the 4 kittens followed longitudinally from 10 weeks on had by 15-16 weeks at least sniffed at the object. Between 6 and 7 months, when the object was covered in this manner the kitten would begin wandering about the area where he had last seen it, emitting sharp cries.

*Table 1.*

| *Test stimulus* | *Response scored as positive* | *No. Ss responding positively* Group 1 | Group 2&3 | Group 4 | First appearance in longitudinal data |
|---|---|---|---|---|---|
| 1. Auditory stimulus (click) off one side | Head turns in direction of sound | 4 | 8 | 7 | 4-5 |
| 2. Object swung in circle around kitten | Head follows object as far as possible, then turns in opposite direction | 0 | No data | 0 | 13 1/2 |
| 3. Object placed in front of kitten and moved slightly | Batting on object | 4 | 8 | 7 | 5 1/2 |
| 4. Object and kitten placed on stool | Kitten knocks object off stool and follows object to floor | 0 | 8 | 7 | 7-8 |
| 5. Kitten playing with object—auditory distraction introduced | Kitten returns directly to object after distraction | 0 | 8 | 7 | 10 |
| 6. Kitten playing with object—visual distraction introduced | Kitten returns directly to object after distraction | 0 | No data | 7 | 9 |
| 7. Kitten is distracted from playing with object—object is covered while kitten is distracted | Kitten pawns at cloth; kitten paws at cloth and uncovers object | 0 | 0 | 3[a] | |
| 8. Object is covered while kitten is playing with it | Kitten paws at cloth; kitten paws at cloth and uncovers object | | | | |

a. Except for the one kitten in Group IV who succeeded in uncovering the object, the pawing behavior referred to here was more like the tentative patting of very short duration (less than 5 seconds).

Of course, the failure to pursue or search for an object may sometimes represent loss of attention or lack of interest, rather than the absence of object permanence. There are 2 major reasons for rejecting this explanation of the results. First, the tests were very brief, and well within the kitten's attention span. Second, the specific behavior patterns scored as negative responses do not appear to involve loss of attention but do involve the lack of one or another aspect of object permanence. See, for example, Tests 2, 7, and 8.

*Test 8: Object Covered While Animal is Playing with It*

None of the 10-12-week-old lab-reared animals attempted to pull at the white cloth covering the object. 2 out of 7 of the 10-13-week-old house-reared kittens pawed at the cloth. One of these animals discontinued the pawing behavior before uncovering the object; the other pawed at the cloth until the object was uncovered and then resumed playing with the object. All of the older lab-reared animals pulled at the cloth, usually until the object was uncovered and then resumed play with the object. The earliest instance of uncovering the object appeared at 16 weeks. But the behavior pattern leading to this particular case was quite distinct from the seemingly more purposeful pattern which appeared in the following weeks in the kittens studied longitudinally.

The longitudinal data reveal an interesting progression of responses in this test. The youngest kittens would respond to the covered object by simply walking away, or, occasionally, by lying down. This constituted an abrupt and striking change in behavior since the kitten had only seconds before been actively batting at, chewing, and generally frolicking with the object. As the kittens matured, this pattern gradually shifted to include a period of preliminary orientation toward the now covered object; even including sniffing at the covering cloth, before walking away. Around the age of 15-16 weeks a new pattern of behavior emerged. When the experimenter covered the object with the cloth, the subject would immediately go up to the cloth and sniff at it and perhaps also tentatively paw at it once or twice. Then, almost invariably, the kitten would walk around the room, sniffing all the time, following in reverse a path very similar to that which he had followed while playing with the object from the beginning of the test situation until the point at which it had been covered by the experimenter. At about 24 weeks of age this behavior was replaced by a new response: The kitten now immediately and vigorously pawed at the cloth covering the object, until the object was uncovered.

## DISCUSSION

The present study has probably delineated only 4 major stages in the development of object permanence in the cat, although a definite effort was made to design tests which would permit observation of the 6 stages described by Piaget in his work with children.

In the first stage, the kittens in this study displayed no particular reaction to the auditory and visual stimuli used in Tests 1 and 3 although their eyes were open during the second week of life. Since this stage lasts for the first 4 weeks of life, it is reasonable to suggest that the kittens during this period were primarily responsive to olfactory and tactual stimuli involved in feeding. The beginnings of positive response to the auditory and visual stimuli occurred about one week after a sharp increase in the kitten's approaches to the mother for feeding as described by Schneirla, Rosenblatt, and Tobach (1963).

The second stage is defined by the appearance of simple sensorimotor coordinations, such as turning the head toward a sound, or tracking an object while it remains in view. This stage appears at about 4 weeks of age in kittens. A characteristic response pattern at this stage of development is the way in which the kitten arrests its tracking movement at the point of disappearance of an object being swung in orbit around him, and then displays a startle reaction when the object appears again on the other side. If, however, the object is swung slowly enough, the subject can and does follow it continuously. For Piaget (1952c) "the child's initial search ... is only an extension or repetition of the most recent acts of accommodation [p. 13]." Thus, the child and the kitten, at this stage, continue looking at the point of disappearance of the vanished object.

The distinctions between the first and second stages are reasonably clear: In the former (0-4 weeks), the kitten does not respond with gross bodily activity to auditory and visual stimuli; in the latter (4-7 weeks), he does. This means that he orients toward objects, plays with them, and pursues them with a growing repertoire of behavior. In the third stage (7-16 weeks), the kitten can follow the trajectory of a vanishing object and can return immediately to an object after some distraction. In the fourth stage (16 weeks onward), he exhibits true search: hunting persistently for a vanished object, ceasing to hunt and orienting toward the object when he finds it.

Some of these distinctions can be clarified by a more detailed description of two kittens observed at 9 weeks.

When either kitten knocked the object off the stool, he followed it down promptly—a pattern which first emerged between 7 and 8 weeks. When the experimenter introduced a visual distraction both kittens responded to it; when it was removed, one returned promptly to the original object it had been playing with, the other did not. Neither kitten returned to the object after being distracted by an auditory stimulus.

In other words, when the kitten-object relation was altered by means of an action taken by the kitten, the kitten was likely to stay with or return to the object. But if it was the experimenter who disturbed this relation, the movements of the object were not coordinated with actions of the kitten in quite the same way. Similarly, in observing his children, Piaget noted the tracking of the trajectory of a disappearing object at an earlier age when the child himself dropped it than when Piaget dropped it.

When an experimenter covers the object with a cloth while the subject is in the act of reaching for it, the kitten at this age does *not* search for the object under the cloth; the kitten may walk away and lose interest in the object (and cloth) entirely, or he may transfer his attention to the cloth, or he may look around as though searching for something. But at this stage he does not search for the vanished object. The third stage is characterized by two response patterns indicating the beginning of object permanence. The first pattern may be regarded as an extension of earlier coordinations of vision with prehension. For example, the kitten bats with his paws at an object moving in front of him, in his field of view; at 7-8 weeks of age this pattern is extended to include jumping off a stool in pursuit of an object which the kitten has knocked down. As the object goes out of sight during the latter sequence, the object is no longer sought only where it has recently been seen but is looked for in a new place.

The second characteristic pattern of the third stage exemplifies Piaget's concept of deferred circular reactions: the return, after a momentary visual or auditory distraction, to an object that has previously commanded attention. In our kittens, this response pattern appeared at 9-10 weeks of age.

The fourth stage is characterized by the emergence of true search. It can best be understood by contrasting the behavior of the kitten that does not display it with the behavior of the kitten that does. While the kitten is actually playing with an object, the experimenter drops a cloth over it. The 12-week-old kitten suddenly stops orienting toward the object or toward the cloth covering it; he may continue to look at it for a second or two and may tentatively pat the cloth, but then he wanders off. The 20-week-old kitten immediately paws at the cloth vigorously and persistently until he recovers the object. This behavior persists for as long as a minute or two: if the cloth is too large for the kitten to manage easily, the kitten may eventually lose interest before uncovering the object, but not immediately and not very suddenly.

Piaget's Stage V, an extension of true search, is characterized by the child's ability to go directly to an object which has gone through a series of visible displacements, punctuated by occasional concealment of the object in different locations. The present method did not permit the study of Stage V in cats, because the animals pursued the visible, moving object too persistently. The greater speed of the kitten, as compared with the child, would have required the authors to use a restraining apparatus. On the other hand, casual observations suggest that cats may never attain Piaget's Stage V. For example, a cat 35 weeks old, while playing on a table top, knocks a straw down onto the floor. As the subject poises to jump down after it, the experimenter picks up the straw. The cat's head movements indicate that it follows the path of the straw in the experimenter's hand, but the subject jumps down anyway, then circles around uttering a sharp cry typical of this cat when it is searching for something.

In Piaget's Stage VI, the main criterion is the subject's ability to return to and search for an object after a distraction, during which the object has been covered. This behavior has not appeared in any of the animals tested in this study. The two cats still under observation at age 7 months began to show some signs of searching for the vanished object, but *not* specifically in the place where they had last encountered it.

The lab-reared animals tested at 2 years of age did not exhibit Stage VI behavior. It remains possible, of course, that house-reared animals might show this behavior at ages later than those studied so far.

In general, lab-reared kittens seem to develop behavior relevant to object permanence at somewhat later ages than house-reared kittens. For example, none of the 10-12-week-old lab-reared animals exhibited the two kinds of behavior characteristic of the third stage, whereas all of the 10-13-week-old house-reared kittens did. This result remains somewhat ambiguous due to the absence of a split litter control, and the small N.

To sum up, kittens begin to develop a repertoire of response patterns indicating some limited kind of object permanence in much the same sequence as children, but considerably more rapidly. The kittens probably reach a ceiling somewhere around the age of 6-7 months. Children eventually develop a fuller notion of object permanence which, as Piaget and Inhelder (1966) have pointed out, provides the basis for further intellectual growth.

# Introduction to the Essential Piaget

*with Jacques Vonèche*

"A man, therefore, who gets so far as making the supposed unity of the self two-fold is already almost a genius, in any case a most exceptional and interesting person. In reality, however, every ego, so far from being a unity is in the highest degree a manifold world, a constellated heaven, a chaos of forms, of stages and stages, of inheritances and potentialities ... not yet a finished creation but rather a challenge of the spirit" (Hesse, *Steppenwolf*)

A tribute to the human need to know: the baby's delight in her first amazed discovery of her own hand, or that a parent comes when called, or that an object fallen from her grasp remains much the same when it is regained. Another tribute to the same need to know: scientific theories on all subjects repeatedly capture widespread public attention.

Psychological theories touch a special chord, our natural interest in ourselves and in each other. Different theories, although they may be seen as competing for the best way of integrating psychological knowledge, can also be viewed as reflecting different aspects of this complexity of self and social interest.

Only a few psychologists in our century have approached the status of household word: Freud and his lineal descendant Erikson, Pavlov and his lineal descendant Skinner, and Piaget. To understand Piaget's particular impact, it is useful to reflect a moment on the differences among these points of view. Psychoanalysis focuses its attention on the animal, irrational, unconscious aspects of human experience and conduct. It promises amelioration of human ills through new techniques for establishing healthier relations between the rational, which it does not deny, and the irrational, which it acclaims. Behaviorism challenges the simplistic rationalism of previous centuries from another quarter, denying scientific status to the very idea of consciousness, and promising control of behavior through the management of external stimuli and rewards. Whatever their raisons d'être, or their merits, neither psychoanalysis nor behaviorism dwells on certain essential human characteristics from which we derive our species name *Homo sapiens*: we think, we know, we act knowingly, we strive for greater knowledge and understanding.

Piaget's whole scientific effort addresses itself to this human need to know. When he received the *Distinguished Scientist Award* from the *American Psychological Association* in 1969, the citation included this sentence: "He has approached questions up to now exclusively philosophical in a resolutely empirical manner, and has made epistemology into a science separate from philosophy, but related to all the

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human sciences." Piaget promises nothing direct in the way of practical application of his ideas, although others have drawn on his work for various purposes. He offers only a point of departure for that unquenchable curiosity that resides somewhere in each of us, to know more, to understand the sources of our own knowledge, to understand others by grasping how they have come to think as they do.

But he does not provide satisfaction in the form of a brief or easily summarized formula. One of his greatest merits, his scope, is also one of the sources of his readers' greatest despair. His ideas and discoveries are spread out in some fifty books and hundreds of articles. In his work as a psychologist, for which he is best known, he has tried to show the childhood origins of human knowledge in almost every sphere: logic, space, time, chance, morality, play, language, mathematics. He has dealt with a wide spectrum of psychological processes: reasoning, perception, imagery, memory, imitation, action. Beyond this, or rather interwoven with this vast effort, is his concern with elaborating a philosophical point of view, genetic epistemology, and with exploring in considerable depth its biological as well as its psychological implications.

In the present work we attempt to reduce Piaget's entire oeuvre to one volume. But a question remains: Can there be an *essential* Piaget? Is there a body of thought so fixed and stable that it can be captured and pinned down in any single volume without destroying its vitality? Piaget's incessant literary output can be understood to mean that his system or essence remains permanently under construction. He has said that he cannot think without pen in hand; for him thinking is writing. The products of his pen are not so much fixed ideas or "findings" or essences as they are the very flow of his thought.

In keeping with this view, our introduction is not an attempt to provide a simplified summary of what is to follow. Rather, we try to give some sense of the restless interplay between a few major ideas, with special attention to the tensions produced, the unanswered questions. Our aim is to encourage the reader to join in thinking with Piaget about the next steps to be taken in the construction of knowledge. For us, that is the essence of Piaget's several essences.

Piaget's work whether it be thought of as philosophy, biology, or psychology, is all directed at elaborating a theory of knowledge, of how the organism comes to know its world. Among possible theories, at one extreme is the Kantian view that the infant is born with a set of innate or a priori ideas which constitute the fundamental outlines of all knowledge. (Of Piaget's relation to apriorism we shall say more later.) At another extreme (and there are more than two extremes, since theories of knowledge do not comprise a simple linear array) is the empiricist view that the infant is born with no innate ideas, and that all knowledge results from the accumulation of experience, so that knowledge is a direct copy of the reality with which each person is incessantly confronted. Experience in this sense, then, is sensory or perceptual. But experience can be thought of in several ways: Do we mean the direct perception of external reality, which tells us what the world out there is like? Or do we mean our actions upon the world, or better, our interactions with it? And in either case—experience of world as perceived, or as acted in and upon—how is such experience affected by and incorporated into whatever knowledge has been previously acquired? These are the sorts of questions that Piaget's or indeed any theory of knowledge must confront.

We begin our discussion with a few observations made by Piaget at different points in time, all bearing on the relations among perception, action, and knowledge.

## REALITY AND PERCEPTION: ACTION AND KNOWLEDGE

Piaget questions children about the behavior of heavenly bodies:

| | |
|---|---|
| Adult: | Does the moon move or not? |
| Child (age 7): | When we go, it goes. |
| Adult: | What makes it move? |
| Child: | We do. |
| Adult: | How? |
| Child: | When we walk. It goes by itself. (Piaget 1973a, 146-147) |

Neither Piaget nor his young subjects, of course, were the first to notice that the moon seems to move when we do. Every child has seen it move, and adults can too, if they remember to look. Nor was Piaget the only psychologist to notice that children actually believe that their own actions cause the moon and clouds to move.[1]

What distinguishes Piaget's approach is his persistence in carrying the questions posed by such simple observations as far as possible. Piaget's work in the 1920s led him to describe a period of childhood egocentrism characterized by a multitude of examples such as the observation above. Eventually, these efforts led him to search for the origins of egocentric thought in an infantile period of solipsism, in which the baby does not even distinguish himself from the world, and consequently cannot yet have an idea of distinct and permanent objects: there is nothing but a flux of appearances. After his studies of infancy, Piaget carried his questions forward into later childhood. With the emergence of the logic of concrete operations, the child acquires the tools necessary to separate appearances from reality, or to distinguish perception from other forms of knowledge.

Almost fifty years later, one of Piaget's collaborators investigated the child's handling of a contradiction produced by a conflict between a visual illusion and the child's knowledge of the real situation. In this study, for example, two sticks are first chosen by the child from a set of sticks as appearing to be the same size, which they are. Then the experimenter puts one of them in a horizontal position and the other vertical, forming an inverted T; this produces the well-known vertical-horizontal illu-

1. Piaget cites another author, Rasmussen, to this effect. And Anne Roe describes a young child, later to become a distinguished scientist, who sent his little brother down to the bottom of the garden as an experiment to find out whether the moon's movement generated by the child at point A can be perceived by another child at point B. So this is serious business. See Roe (1952).

sion, in which the vertical stick appears definitely longer than the horizontal one. It has been established that children and adults are quite uniformly susceptible to this illusion.

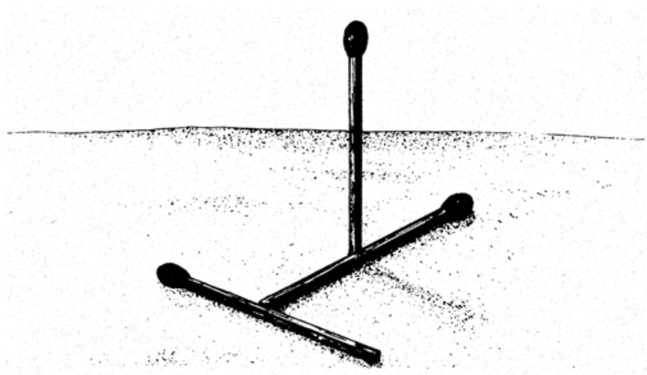

*Figure 1.* When the middle matchstick is seen as bisecting the lowest matchstick, it is seen as longer. When it is seen as bisected by the topmost stick, it is seen as shorter. (You can do this with three matchsticks in one plane, too.) Since we know that all three are the same size, this illustrates a contradiction between knowledge and perception.

Experimenter: (Puts sticks in inverted-T position.)
Child (6;6) : They are both the same size.
Experimenter: But when you look at them, they are the same?
Child: Yes.
Experimenter: You see them the same, or you only know it? When you look at them, isn't there a big one and a small one?
Child: I see them the same.
Experimenter: What did you do?
Child: I saw that they were both the same size.
Experimenter: When did you do that? When you chose them, or now while looking?
Child: Before and now. (Piaget and Gillièron 1974)

Another child gives a much less common reaction. When the sticks are presented in the illusion configuration, she sees the illusion, but changes her belief as to their length: if it looks longer it is longer.

Although the two children seem quite different, they have an important point in common, an insensitivity to contradiction, an inability to deal with it. One eliminates the problem by denying the illusion, the other by sacrificing his previous judgment that the sticks were equal. By the time they are about eight to ten years old both children will be able to accept the apparent contradiction and deal with it in a more stable logical framework. In this later research it is not so much the child's grasp of the distinction among perception, action, and knowledge that interested Piaget; rather it is the growth of awareness of contradiction, the will to search for ways of thinking that can eliminate contradiction, in short the growth of logic.

From these observations, the "movement" of the moon and the changing size of objects in visual illusions, we might conclude that perception is not a reliable guide to knowledge, that if we permitted ourselves to be guided by our direct perception of the world we would often fall into serious error. This might seem adequate to refute the empiricist view that knowledge originates in our perception of the world. Not so. The empiricist can and does readily answer: of course, perception is unreliable, knowledge fallible, and only the accumulation of experience helps to reduce error.

Piaget's critique of empiricism runs somewhat deeper. Distinguishing perception from other forms of knowledge is not enough. In some sense perception is of no direct use at all in informing us about the world. It is our previously elaborated understanding that enables us to make any sense of what we perceive. Consider the following example, Piaget's celebrated experiment on the conservation of matter:

> The child is given two containers A and L of equal height, A being wide and L narrow. A is filled to a certain height (one-quarter or one-fifth) and the child is asked to pour the same quantity of liquid into L. The dimensions are such that the level will be four times as high in L as in A for the same amount of liquid. In spite of this striking difference in the proportions, the child at this stage proves incapable of grasping that the smaller diameter of L will require a higher level of liquid. Those children who are clearly still at this stage are satisfied that there is "the same amount to drink" in L when they have filled it to the same level as A. (Piaget 1952a, 11-12)

Now the child can very well "see" that nothing has been added or taken away. But he cannot see it in a way that leads to the conclusion that matter has been conserved until he can carry out a certain group of mental operations on the events before him. Thus it is not through direct observation, but through the actions we carry out upon our perceptions, not so much the actions of the body but those of the mind, mental operations, that we come to know the world. It is not only our knowledge of the world, but even more important, mastery of these operations, that must be constructed in the course of cognitive growth.

Even after long study and reflection and immersion in the subject, it is astonishingly easy to slip into taking for granted that something obvious at one level of development is obvious at other levels. To get the full flavor of how tenacious and puzzling such problems can be, consider another example.

Piaget writes, "in a closed system of physical transformations nothing is created and nothing destroyed ..." Is this a statement of the principle of the conservation of matter? We put this question to a number of Piaget's advanced students and collaborators, all of whom answered in the affirmative. Yet the full quotation reads as follows, "Clearly, it is one thing to observe that in a closed system of physical transformations nothing is created and nothing destroyed, and quite another to infer from this a principle of conservation" (Piaget 1970a, 715). Piaget's meaning is plain enough in its context. The identity operation (nothing added, nothing taken away) is not enough to establish the full idea of conservation of matter, because changing the shape of something (e.g., flattening a clay ball into a "pancake") might conceivably change its amount. Moreover, the inversion operation (changing the shape back again and noting that the original amount is regained) does not entirely solve the problem, because the amount might still have been different while the shape was changed. Only when these two operations are combined with the compensation operation (in changing shape, a decrease in height is compensated for by an increase in diameter, etc.) can a stable solution to conservation problems be found.[2]

Thus, observation alone does not open the way to correct inferences, or for that matter to any inferences at all. Mental operations must be carried out on observations, and these operations themselves develop in the life history.

## AN ONTOLOGICAL QUESTION

In all this, does Piaget mean to say that there is a reality external to the behaving and experiencing person, to which the individual gradually and imperfectly attains, and that it is the steady presence of this reality that regulates and corrects the course of adaptive cognitive growth? This is a plausible interpretation of Piaget's position and seems to be strongly implied by much of his activity as a scientist. It is certainly part of the interpretation of Piaget that has led dialectical materialists to claim him as one of their own kind. But when asked questions to this effect, he is likely to reply, "Je m'en fous de la realité." (I don't give a damn about reality.) Seemingly a strange response from a man who has written a book entitled *The Construction of Reality in the Child*.

What can he mean? One possible alternative is the following. The individual and the social group are constantly in the process of constructing and reconstructing their views of the world. At a given moment, the most advanced (complex, flexible, adaptive) achievements in the pursuit of knowledge may play a regulatory role with regard to other achievements still to be made. But this does not give either the most advanced, or for that matter, as some would have it, the most primitive, kinds of knowledge the status of an ultimate "reality." The main fruit of genetic epistemology is this discovery that the only way in which we get knowledge is through continual construction, and that we can have no enduring knowledge without actively maintain-

2. Another way of putting this: The identity operation refers to the past, because nothing has been added or taken away; the compensation operation is oriented toward a continuous present, during which changes of one kind correspond to changes of another kind; the inversion operation refers to a hypothetical or anticipated future, in which the preexisting situation is restored. Taken altogether, these operations thus provide an account of the uninterrupted existence of the property in question, i.e. conservation.

ing this process. Something else, therefore, will surely be constructed, something that still lies ahead, that will replace whatever the naive realist chooses to canonize today. And so on ad infinitum.

At this point the reader may wish to say, "Je m'en fous de la discussion. It is only philosophy and has nothing to do with psychology." We do not wish to provide a facile answer to the ontological questions posed above. But we do wish to stress the importance of Piaget's patient transformation of difficult philosophical questions into manageable psychological ones. In the particular instance, his lifelong strategy has been to transform seemingly unmanageable ontological questions (what is reality? what exists?) into manageable epistemological questions (how do we know? how do we get knowledge?).

## THE CONCEPT OF STAGE IN PIAGET'S THEORY: SOME QUESTIONS

That there are definite stages of development, which occur universally in a fixed order, is now probably the best known of Piaget's ideas, and seems to be central to his theory. But there are some important questions not easily answered by reading Piaget's work, because, although he has used it for a long time, in fact he has not written a great deal about the stage concept.

### *Range of Application*

Does the stage concept apply only to the three major "periods" of development (sensorimotor, concrete operations, formal operations), or does it also apply to the progressive steps or substages in the attainment of a cognitive structure within a stage? A repeated theme in his frequent brief discussions of the stage concept is the inclusion of attainments of earlier stages in the structures of later stages: an earlier stage is neither discarded nor displaced nor "grown out of"—rather, a later stage is "grown into," and depends on the prior attainment of earlier stages, hence the idea of necessary order. This is an easy enough point to establish convincingly if one considers the relations among the three major stages. It seems self-evident, for example, that the idea of the conservation of matter (attained between six and ten years) rests on and includes the idea of object permanence (attained between one and two years). But it is not so self-evident that the substages described in the *Origins of Intelligence* (1952c) (dealing with the first one to two years of life) necessarily follow in the order described, or just what attainments of the earliest substages are retained in the later ones. This point is of particular significance to teachers of children in the age range five to eleven, the period in which concrete operations are being acquired. It is not very helpful to know that a six-year-old must some years ago have developed the semiotic function to the point where he can talk, or that some years later, in adolescence, if all goes well, he may reach the stage of formal operations. It is helpful to know that developments within the period of concrete operations generally follow certain lines, display certain substages; and it would be important to establish that this is a necessary order. Piaget's own work in Geneva established the existence of the basic sequences under discussion; beginning one or two decades later, the work of various followers established that much the same sequence indeed occurs in widely varying cultures; the demonstration that this sequence is logically necessary remains to be done. It might be added here that experiments that attempt to accelerate the child's movement through a well-known sequence, whether they succeed or fail, do not touch the question of the immutability of the order itself.

When the period of formal operations is reached in adolescence, does stagewise development cease? If so, does this mean that all development ceases, or, alternatively, that later cognitive development is so individualized or has other properties such that it cannot be described in terms of an orderly progression of universal stages? Neither alternative is very satisfying. The one disposes of developmental change for the greater part of the life span; the other proposes that development need not be stagewise. To say either we can have life without development or we can have development without stages seems quite unlike Piaget.

### *Evidence for Stages*

The one point that Piaget has made most insistently is that developmental stages occur in a constant order. On the empirical side, the main evidence for this is that the number of children displaying a certain way of thought or kind of behavior increases with age. To show that the sequence is universal, the same observations must be repeated under widely differing circumstances. When such cross-cultural studies were done, and were found in the main to support Piaget's views as to the universality of cognitive stages, he was not dissatisfied. To show that the sequence is orderly requires a kind of work that has not yet been done on any important scale; to show that any sequence is orderly means to show that the observed sequence corresponds in some way to another sequence which is deemed orderly. Thus, growth in stature is orderly in the sense that the observed sequence of heights corresponds to a sequence of increasing numbers, i.e., age. If children grew and shrank and grew again, the way snowbanks do, we would have to look elsewhere for a criterion of order. To show that the logical structures underlying thought grow in an orderly way, we must have a method for ordering logical structures that is independent of any observations we may make of children's growth. Piaget has concentrated much of his effort on showing that the thought of the child at a given age (or stage) corresponds to a given logical model; this is something less than showing orderly growth.

A thoroughgoing empirical defense of the stage concept would require an investigation of the stability and the coherence of any hypothesized stage. To demonstrate stability, we would have to show that the same child exhibits the same characteristics over the period of time presupposed in the definition of the stage. Piaget has done this very impressively even if nonquantitatively in his studies of his own three children, especially in *Origins of Intelligence* and in *Construction of Reality*. But in the vast panorama of his later works, nothing resembling test-retest reliability can be found because the same child is not seen twice in one study. On the other hand, a certain estimate of stability is built into testing procedures developed by Piaget and his group. The child's initial responses to a given task are not the only evidence adduced; the child's resistance to countersuggestions is routinely tested as well. Moreover, the decision that a given child is at a given stage in the development of a concept is often not based on one narrowly circumscribed task, but on her performance on a group of closely related tasks, so that even if there is no evidence for stability over periods of time such as a week or a month, there is a kind of evidence for consistency in performance.

Another argument in favor of the stability of performance within stages emerged as a result of a series of experiments on the learning of cognitive structures, performed in Geneva. In the late 1950s, a group of Piaget's collaborators conducted a series of experiments, often with great ingenuity, intended to show that the child could progress more rapidly in the development of certain cognitive structures if she were subjected to a carefully worked out training program. The results were disappointing: little or no such rapid change could be detected. But Piaget was not disappointed. These results supported his claim that the structures under discussion develop slowly and primarily through an internal process of construction, rather than representing direct and immediate copies of environmental events.

To demonstrate coherence, we would have to show that the same underlying logical model underlies the child's performance in widely differing tasks. Again, this requires testing the same child in different situations, which has not generally been done. Different groups of children are used in different studies, making such comparisons impossible. This leaves us with the plausible but not demonstrated inference that if we had tested the same child on a wide variety of tests she would have behaved in a way governed by the same logical model. If all children developed at the same rate we could, of course, substitute one child for another of the same age, and thus avoid testing the same child too often. But if, as is generally agreed, children develop at different rates or if each child shows a certain amount of unevenness in his development, such substitutions are invalid.

The unevenness of development, under the name of horizontal décalage, has entered Piaget's theory both as a matter of fact and of theory. On the factual side, although there has been no thoroughgoing systematic effort to define the amount of coherence a stage would need to have in order to qualify as a stage, or exhaustive empirical effort to study intertest correlations, there has been an accumulation of evidence showing that development is local, spotty, and uneven. A concept may appear in one form, but take a year or more to extend itself over its possible range. On the theoretical side, this unevenness, or décalage, has been used by Piaget as one explanatory principle for development: the very coexistence of the more highly developed and the less highly developed structures generates disequilibrium or conflict that leads to further growth. But how much unevenness is acceptable within a stage theory without undermining the very concept of stage?

*Function in the Theory*

Is the stage concept an essential part of Piaget's theory? If it were essential, we would expect him, sometime in the fifty-year period in which he used it, to have elaborated it at the same length and with the same care he has given to other ideas: this he has not done. It is reasonable to ask, what would remain undisturbed in Piaget's theory if the hypothesis of a single, orderly, and universal succession of stages of cognitive development were dropped? There is, of course, a great deal more to Piaget besides the stage concept but it cannot be clear without a major theoretical effort how other parts of the theory would be affected. It seems plausible to suggest that Piaget's interactionism, his ideas of assimilation and accommodation, his recent equilibration model, the idea of progressive decentering, and his elaboration of the idea of intellectual operations—all these might stand without the stage concept. On the other hand, his search for a progression of different logical models underlying thought at different points in development and his emphasis, especially in later years, on the hierarchical growth of cognitive structures seem more closely linked to the stage concept.

Another possibility worth considering would be to weaken the definition of stage by dropping the idea of universality. Intellectual growth could be orderly and could correspond to series of logical models without following one universal developmental pathway. Piaget himself well understands that it takes a complex system of forces to maintain development on its observed course; he has borrowed Waddington's concept of homeorrhesis to express this idea. (For a brief sketch of some of C. H. Waddington's ideas, see Waddington 1969). It takes only one further step, also proposed by Waddington, to recognize that development is eminently polymorphic, and that when the forces making for one choice of developmental pathway (*creode*) are not strong enough, the organism will develop in another way. This step can be taken without admitting that development is helter-skelter, subject to every wind of chance. The proposal that there is more than one *creode* available does not undermine the central idea of orderly growth.

If Piaget's stage concept be not essential to his theory, what role does it play? We propose two major functions. First, it is a descriptive tool. The biologist must first describe and classify the major forms of life before he can even raise the question, how does one form evolve into another? Piaget began his career as a biologist working in just this way. When he moved into psychology, he took this strategy along with him. Describing the stages of growth, even in a first approximation, gave him the point of departure he needed for raising the dynamic and genetic questions: how does the organism maintain its present structure and how does it change?

Second, Piaget's use of the stage concept is an expression of his remorseless anti-empiricism. During a given stage, the person does thus and so, and he can do no other. To change as a mere reaction to environmental pressure would be to violate the organized integrity of the individual in his given stage of development. Change is a serious matter; to accomplish it the individual must reconstruct himself.

When we question the central role of the concept of a universal series of ordered stages in Piaget's theory, we do not mean to question the importance of the idea to Piaget's work. One looks in vain through his writings, all the way to 1955, for an extended discussion of the stage concept. Even this paper is brief and does not go into very great detail. But Piaget takes the idea of stages for granted, and uses it vigorously as a framework on which to organize his findings during the whole of the thirty-six-year period from 1923 (*Language and Thought of the Child*) to 1959 (*The Early Growth of Logic in the Child*). In the *Origins of Intelligence* the opening chapter is a theoretical sketch of Piaget's views, recapitulated in the closing chapter of the companion volume, *The Construction of Reality*. In neither place does Piaget elaborate on the concept of stage as a theoretical idea. But throughout the body of these two great and seminal works, all of Piaget's observations are presented in the form of a series of stages. What shall we conclude: Theory is as theoretician says, or as empirical scientist does?

In the longer reaches of time over which science evolves, we may find a firmer basis for deciding whether there are fixed and universal stages of cognitive growth, whether these have sudden or gradual onsets and offsets, whether they are coherent and unitary characteristics of the intellect as a whole or uneven in their development over a rather disjointed intellect, whether they can be much modified by variations in experience, and what determines whether the individual remains in a stable phase or undergoes a period of change. Meanwhile, without our having firm answers to any of these questions, Piaget's work stands as a major landmark in the history of knowledge, because within the framework of the unexamined concept he has given brilliant description one after another of the changing intellect of the child.

## PIAGET'S THEORY OF INTELLECTUAL PROCESS

By this time the reader may well believe we are arguing that Piaget's theory is unimportant and only his observations matter.[3] Not at all. We propose only that other parts of Piaget's theory are far more important than the stage concept, and we hope to draw the reader's attention to them. Piaget offers a theory of how the intellect grows: at any point in its development, it may be described as a set of organized structures or schemes; as the individual encounters his world, he assimilates objects and events to these structures (thus they function and expand without structural change); when this is not possible because the existing structures are inadequate, they modify themselves or accommodate (thus they undergo structural changes). At first the child is unaware of himself or the world or the distinction between them, but he becomes increasingly aware, and finally conscious of and capable of reflecting upon his own intellectual processes; thus he gains a new level of command over his thought and its growth.

3. In Piaget's view this would be almost a mortal sin, since he has devoted so much of his energy to the struggle against just such an empiricist view of the growth of knowledge both in the child and among scientists.

There is much more to the theory, but we refrain from expanding on it here. Throughout this volume there are theoretical passages which we have not slighted in our selection.

Here we wish only to stress the point that for Piaget the growth of the intellect, rather than something that happens to the child from the outside, is a process of self-construction, governed by existing formations of cognitive structures. To be sure, it happens in relation to the world, and it is a process that has evolved in such fashion that its results are biologically and socially adaptive; the world plays its regulative function. But it is not a matter of stimulus and response, push and pull. Rather, environmental events are assimilated as well as they can be to existing structures, chewed over and digested, and, finally, only occasionally do they result in fundamental changes in such structures.[4]

Piaget is not the only case in the history of science where great theoretical interest attaches to the interplay between the description of fixed entities, such as species or stages, and the process of change. Darwin, in developing the theory of evolution, had to use as his point of departure whatever was already known about species, especially as organized in a masterly array by his great predecessor, Linnaeus, a century before. Marx, in developing his theory of social change and the functioning of the capitalist system, drew on what was known of the major stages in the evolution of economic forms. Both Darwin and Marx had to argue against earlier theories of change in which a fixed order was given in a metaphysical law of progress. There were evolutionary theorists before Darwin who believed that the explanation of evolutionary change lay simply in a tendency toward progress inherent in the natural order (and perhaps preordained by the Creator). Darwin's alternative was that change grows out of the functioning of the system of living things as it is (See Gruber 1981e).

Similarly, there was a current among nineteenth-century social theorists to explain history as a series of necessary and foreordained economic stages (such as food gathering, pastoral, slavery, feudal, bourgeois, socialist, and so on). Like Darwin, whom he greatly admired, Marx argued that social change grows out of the struggles inherent in the existing social order: "*History* does *nothing*, it possesses no immense wealth, it wages no battles. It is man, real living man, that does all that, that possesses and fights; "history" is not a person apart, using man as means for its own particular aims; history is nothing but the activity of man pursuing his aims." (Marx 1970, 87).

Freud, in developing his theory of the growth of personality, postulated a series of psychosexual stages (oral, anal, phallic, latent, genital), which he then proceeded to explain by a group of psychodynamic principles. It is instructive in Freud's case that

4. There is some room for discussion as to whether Piaget believes that change is continuous or sporadic. In our view he makes a distinction on this score between assimilation and accommodation: "assimilation, the fundamental fact of psychic development," he writes in his theoretical introduction to the *Origins of Intelligence* (p. 42); we believe he treats assimilation more thoroughly than accommodation and regards it as more fundamental. Maybe it is true that in some sense it is more characteristic of an organism to go on functioning as it has done, to preserve its identity, than it is for it to change.

one can separate his stage theory from his psychodynamics. We have been suggesting that the same is true of Piaget. But there is a difference. Freud's theory of psychosexual stages was a rather long-range inference about children, based on his work with adult patients.[5] Piaget's theory of cognitive stages is based on years of work with the children to whom it refers. We may also note that Darwin did not have to assemble the evidence for the existence of species or to construct a taxonomy *de novo*, nor did Marx have to demonstrate the existence of different social forms and classes. Thus, Piaget had a truly Herculean labor to perform: he had to discover and describe the very rudiments of the course of cognitive growth at the same time as he developed a theory to explain it.

One has only to compare Piaget's efforts with others of similar intent to see how much needed to be done. Piaget succeeded in transforming each of the Kantian categories of knowledge from a first principle into a subject of scientific investigation to which he contributed the first significant monograph. Enormous energy, persistence, and the privileged position of a university professor were important requirements, but by no means enough to explain his feat. Piaget was guided by certain abiding philosophical and biological concerns that gave him the sense of abiding purpose that was indispensable for the task.

## STRUCTURES AND OPERATIONS

It is the great task of science to search for unifying descriptions and explanations, to illuminate likenesses that underlie apparent differences in the manifold of nature. There are three great strategies of search: to look for laws, elements, or structures. Our knowledge of the laws of physics, the elements of chemistry, and the structures of biology represents the fruits of such efforts. Of course, the three strategies are not kept in separate portfolios, to be brought out exactly as needed. As we begin to explore a domain of nature, we do not know what to expect or how to proceed, what strategy or combination of strategies will be most helpful. There is, moreover, a constant interplay of strategies. For instance, the gas laws (relating pressure, volume, and temperature) are general laws that describe the behavior of quantities of gas in closed containers, but these quantities are made up of elementary particles or molecules, and when we understand the nature of these elements, we understand why the gas laws must be modified in significant ways.

5. This is not intended as a deep criticism of Freud, since he was not primarily interested in children, and wanted mainly to use the stages to help develop his psychodynamic ideas.

But what do we mean by the "nature" of an element? In good part, its internal structure.[6]

In the social sciences, nothing is as familiar as Adam Smith's law of supply and demand. This is quite similar to the gas laws in that it describes the reciprocal relationships between variables that determine the form of a complex event, the fluctuation in price of a commodity. But the elements in this process are the individual buyers and sellers, and their social and psychological characteristics must be examined if we are to understand the conditions under which the law operates. Furthermore, these individuals are not isolated human particles who just happen to be brought together in a container called the market place; they are part of a complex social structure, a class system with a certain distribution of rights of property and exploitation, institutions of education and law enforcement to ensure that individuals play their roles within the system. Without all this the market would not function as it does. Thus, law, element, and structure are indissociable.

Nevertheless, in the work of an individual scientist or of a group in a particular epoch, we may find a penchant for one or another strategy. Piaget is widely known as a structuralist, but his structuralism takes a specific and interesting form. To understand it, it will be helpful to examine the theoretical scene in psychology and to distinguish Piaget's concern for structures from others.

Psychology as an organized science got its start in the middle of the nineteenth century and was less than a century old when Piaget began his psychological studies in Paris in 1921. During the period about 1875-1925 one of the dominant currents of thought was an introspective variety of elementarism: first find the elementary sensations of which experience is composed, then see how more complex structures are built up from these elements.

Beginning about 1912, Gestalt psychologists, challenging the very existence of such elementary sensations, argued that experience occurs as structured wholes and that the task of psychology is to study the properties of such wholes. The properties to search for are those underlying invariants that help to explain why experience is not a chaos of diversity, but has organization, unity, stability. Consider the problem of spatial orientation: why does an object ever appear stable and upright? At any one moment, depending on the position of the head, it may stimulate this or that set of retinal receptors, or "elements," which may or may not be aligned with a major bodily axis. Yet the object does not seem to change its orientation with every movement of the head. What remains invariant is the relation of the object to its background, in particular to the major lines of the visual field. Such invariants are structural proper-

6. The approach which we have called *introspective elementarism* has sometimes been called structuralism; among its leading exponents were Wundt at Leipzig and Titchener at Cornell; it is not to be confused with the contemporary movement known as Structuralism, with which we deal below. The latter began its rise to prominence early in this century and includes such figures as Ferdinand de Saussure in linguistics, Nicolai Bourbaki (pseudonym for an intellectual collective) in mathematics, and Claude Lévi-Strauss in anthropology.

ties of the total perceptual configuration, not any localizable element or set of elements. There is no need to invent elements out of which structured experiences are built; experience is structured in the first place.

Piaget, in his interest in psychological structures, has much in common with Gestalt theory. Indeed, his summaries of it are sympathetic, full, and accurate. But he has one central criticism: the lack of concern for the genesis of the structures under discussion. Thus, in the example given above, Piaget's research has focused on the emergence in the child's thought of the operation of a coordinate system or frame of reference with respect to which things may have an invariant orientation. There would be no necessary contradiction between these two approaches, if these perceptual invariants did not change with age; we might simply have two independent systems of knowledge, conceptual and perceptual. But Piaget has given considerable effort to show that the developing concepts do indeed control the perception of space. In this sense, Piaget is not merely concerned with structures, he is structuralist: he wants to show the general regulative functions of structures, their pervasiveness in controlling experience and action, and the psychological coherence of the individual as the expression of a few very general structures.

To sum up this historical movement of ideas, the elementarists said, "from elements, structures," the Gestaltists answered "no elements, only structures," and Piaget rejoined, "out of structures, new structures."

In spite of his kinship with Gestalt psychology, there are some important differences. Piaget's structures are not things or beliefs, but coherent sets of mental operations which can be applied to things or beliefs or to anything else in the individual's psychological space. For example, the belief in the conservation of matter when shapes are deformed is not, in this sense, a "structure." Rather, the set of operations by which this belief is arrived at is a structure. Piaget does not claim that eight-year-old children all over the world spontaneously discover the conservation of matter; rather, they develop a set of operations that permits them to make this discovery when presented with a problem that can be solved if they do so. What matters is not a particular set of beliefs but a general set of operations.

A second special character of Piaget's structuralism is concern for change. He is not only interested in showing that, at each stage of development, a great variety of acts express the same structure; he is also interested in the way in which structures are transformed from stage to stage. He has given fuller attention to and been more successful at the first of these tasks. But there is no questioning that his aim is a developmental or genetic structuralism. In this respect his intentions are quite distinct from the contemporary structuralist movement that explicitly avoids genetic or historical explanations, choosing instead to elaborate ahistorical analyses of structures as they are at a given moment or period.

If the introspective elementarists were attacked from "above" by Gestalt psychologists, they were at the same time attacked from "below" by behaviorists. Behaviorism is in its own right an outstanding form of elementarism, hoping to explain complex behavior as the chaining together of simpler habits. The introspective elementarists were mentalists in the highest degree: the task of psychology was to explain mental life, and the method was to examine it directly with the tool of mentation itself, trained introspection. The Gestaltists were also interested in mental life and certainly used a type of introspection, or direct examination of experience as one of their tools. But they were also prepared to study the functioning of the intellect by the observation of behavior. One of the great classics of Gestalt psychology is a study of the problem-solving behavior of primates who could not at that time report to psychologists about their inner lives (Köhler 1976).

The behaviorists, as is well known, would have none of this. The whole project of describing inner experience seemed unscientific to them: science deals with observable events, all we can observe and study directly is overt behavior, therefore scientific psychology must restrict itself to the study of behavior. "Inner experience," "consciousness," and all other subjective phenomena have no place in science.

Piaget has rarely bothered to criticize the introspective elementarists. He had no quarrel with their mentalistic aims, and, besides, by the time his career in psychology began, the importance of this school of thought had faded considerably. Why then has he often stopped to criticize the claims of behaviorists? Not to defend his interest in mental life. On the pragmatic American scene that might have seemed necessary, but not in the heart of Europe. We think there are two reasons for Piaget's interest in behaviorism, its focus on action, which Piaget shares, and its empiricism, which he loathes.

First, Piaget's own theory and behaviorism both begin with interest in action. Theoretically, both begin with the simple reflexes of the newborn and aim at explaining development by studying the developmental fate of these reflexes. From this point on, the theoretical differences are profound. Behaviorists aim at explaining all behavior as the modification of simple reflexes through the formation of habits, and the chaining together of these elements to form more complex units of behavior. It would be incorrect to say that behaviorists are not interested in structures, since chains and simple hierarchies are certainly structures; but they are structures of such primitive kind as practically to bypass the problem of organized, complex behavior.[7]

In Piaget's approach, the units of behavior, or schemes of action, are always seen as evolving structures. Thus complex behavior is not built up out of simple elements that retain their identity; instead, structures grow and change. Insofar as they are hierarchically organized, lower structures are governed and regulated by higher ones: rather than the primordial dominating the more highly evolved, the reverse is the case. Finally, Piaget's concern has always been to show how action is interiorized, transformed into mental life, and he insists that in the course of this transformation action becomes qualitatively distinct from its primitive origins. As actions become operations, they form structured groups that give to thought its flexibility, its versatility, its ability to deal with novelty, its creativity.

7. This description of behaviorism is somewhat oversimplified and does not do justice to certain modern trends. See, for example, Berlyne (1965) for an explicit attempt to integrate behaviorism and Piagetian theory. See also Piaget's commentary on Berlyne's efforts in Berlyne and Piaget (1960).

In some sense everything has a structure. If we wanted to develop a theory pertaining to a unique structure, unlike any other, it would have to be an analysis of the elements composing the structure or an account of the laws linking the variables within the structure. The third alternative, comparing the given structure to some ideal structure, necessarily admits the existence of more than one structure. Piaget's way has been the structuralist way, comparing structures with each other, in the first place to show the underlying similarities among seemingly different intellectual acts, and in the long run hopefully to discover the laws of transformation governing the relationships between structures.

The stage concept is necessarily linked to the idea of structure. Whatever we mean by a stage in the development of anything must be a set of relations prevailing at one time. But this is not enough to separate stage from flux. The set of relationships must be stable.[8]

Since we are talking about mental operations, or an activity of an organism that is always changing, we mean something more general than a single, frozen structured act. We mean the similarities or correspondences among different acts. That is why we can speak of the structure as underlying or regulating the acts in question.

A key feature of the kind of structure we are discussing is its coherence and unity: there is one set of rules for passing from state to state, and any transformation or series of transformations that follows these rules is an expression of the structure. Unless the intellect as a whole is completely coherent at each stage of development, we cannot expect to find a clear-cut set of stages (series of structures) without delimiting the domains to which the structures apply.

This leads directly to another consideration, the distinction between structure and system. Suppose we find that there are a number of distinct structures coexisting at any moment of development. These coexist in one individual, and they must have some relation to each other. One possibility is to search for a more general structure, of which each of the seemingly distinct ones is but an expression. The effort to exhaust this strategy, to carry it as far as possible, is the heart of the movement known as structuralism.

An alternative strategy is to accept the structures as different and to search for ways of understanding their interconnections; this approach is characteristic of a movement known as systems theory. As we discussed above in another context, scientific theories are rarely pure cases of any one strategy. Moreover, the approaches in question are not contradictory but complementary, and we may expect to find an individual scientist using first one then the other. But it is fair to describe Piaget as a structuralist rather than a systems theorist. To take only one example, when Piaget turned his attention to mental imagery and memory, he did not delight in showing how different these are from logical thinking, and then seek to understand the rela-

8. This might be enough to say if we could restrict ourselves to a series of stages of long duration. The notion of a brief stage (the measure of brevity depending on the time-scale we are using, which is not the same for the life of both a subatomic particle and a child) really depends on our ability to show that it appears reliably within a series of more stable structures.

tions among these functions. Rather, he sought to demonstrate that at each stage the child's imagery and memory express the same logical structures as had been found earlier in his studies of the child's thinking.[9]

It might reasonably be objected here, that Piaget did not seek to demonstrate, but attacked a problem objectively, and these were his empirical findings. This objection is not entirely available to Piaget himself, since he has strenuously criticized the empiricist view of science. The finding of some similarities, of course, does not conflict with the finding of some differences. The similarities in question were genuine discoveries, and this work is a good example of the fruitfulness of Piaget's approach. At the same time, it should be noted that he did not seek out whatever differences may exist between these functions precisely because he is a structuralist rather than a systems theorist.

The suggestion that a general point of view, such as structuralism or systems theory, may be a causal agent affecting the work of a scientist is compatible with either of the approaches under discussion. Put more generally, the two have one key point in common, the idea of self-regulation; this applies as much to the mind of a scientist as it does to the behavior of any other living system.[10]

## INTERACTION, CONSTRUCTION, AND LOGICAL DETERMINISM

No issue touches the thinking person more deeply than the relation of the individual to the world. Discussion takes many forms and gives rise to a number of questions, the answers to which never quite seem to stay put. The role of the individual in history, the individual's place in the family, and the relative contributions of heredity and environment in determining intelligence—all these raise questions that bear on one's general conception of the relation of organism and environment.

Piaget's approach to the general issue has been open to some misunderstanding. His insistence on the slow development of fundamental concepts and operations has sometimes been interpreted as meaning that the child "learns" these things primarily through commerce with the environment: stimulus evokes response, and, depending on the outcome, future response tendencies are altered, habits built up, but slowly. This is the position Piaget labels "empiricism," and he is very far from agreeing with it. To return to the example of the conservation of matter, what evidence could the child possibly have that amount remains the same when shape is deformed? No one talks about it, or tells her, or asks her about it, or rewards her for giving the right answer. Even more implausible is the suggestion that the child learns the reasons she gives to defend her answer; if we could believe that the child learned the right answer,

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9. A similar point can be made with respect to Gestalt psychologists, who have stressed the likenesses among different mental functions, such as perception, memory, and thinking. For them, perception plays the role of the central metaphor; for Piaget, logic plays that role.

10. As will be especially evident in the final section of this volume, Piaget lays great stress on the idea of self-regulating systems. But systems theories aim to do more than that.

how would we explain where she had gotten the wrong answer and reasons, only a few months before? When we turn to the history of science, as Piaget is fond of doing, we see many examples of resistance to evidence because it does not fit into previously constructed ways of thought. Why, then, credit the child with a facile empiricism, readily fitting thought to experience?

If Piaget has been persistent and relentless in his criticism of empiricism, how does it happen that he remains open to this interpretation? The plain fact is, as he admits, that he has never succeeded in giving a satisfactory explanation of the production of a novel response. This leaves an opening for the application of an old and almost intractable thought-form: if a pattern of responses changes slowly, it must be due to learning.

Piaget has not only insisted on the slowness of development, but on the universality of its main stages. Since children grow up in such varied environments, the question arises, how can they all develop in the same way unless they are impervious to environmental influences, in other words, unless development is determined by hereditary factors? This is the position Piaget labels *preformism* when it refers to matters of general biology, and *apriorism* when it refers to the growth of intelligence.

Every study Piaget has ever made of children's concepts and mental operations shows how far the child's mentality is from being preformed in adult ways of thought, how he must during his own lifetime reinvent these ways. What the child brings to the world makes this growth possible, but the child himself must accomplish it through his own activity.

Nevertheless, if children everywhere do this in much the same way, does it not support the idea that development is an unfolding of inherent structures that are incipiently present in the germ plasm? And is this not a sort of apriorism, only extended over time?[11]

Piaget has been vulnerable to this interpretation of his work because of his insistence on the universality of stages. It would seem incumbent on the interactionist to produce evidence that commerce with the environment does affect the course of development. For this reason, in the 1950s studies of the learning of Piagetian concepts and operations came to occupy an important place in the theoretical discussion. We have already mentioned the first group of such studies. To say the least, they demonstrated that it is not easy to invent a way of accelerating the child development through the stages of cognitive growth, existing structures resist change, the child's mind is no direct copy of the external reality presented to him by experimenter or teacher.

Insofar as this result supported Piaget's anti-empiricism, it seemed quite satisfactory. But it did leave the way open to the "unfolding" interpretation. In recent years, there has been a concerted effort in many quarters to show that Piagetian concepts and operations are indeed amenable to change through learning experiments. And modest results have now been achieved. So long as the experiment is planned in ways

11. For an account of the vicissitudes of the same kind of question in another discipline, during the eighteenth and nineteenth centuries, see Needham (1959).

that respect the child's existing structures and elicit the child's own intellectual activity, some acceleration of growth can be achieved (for an account of work in this vein conducted in Geneva see Inhelder, Sinclair, and Bovet 1974). Since no one actually believes that it is possible to transform a young child overnight into an adult, modest effects are theoretically satisfactory. It should be added, however, that acceptance of this point implies a tacit acceptance of much of the structuralist approach.

To contrast it with empiricism and apriorism, Piaget has sometimes labeled his own position *interactionism*. But this term has often been used in a sense which does not quite fit Piaget. Hardly anyone who considers the subject goes to either extreme: it is widely accepted that the child's mentality is neither entirely inherited nor entirely determined by environmental forces. A compromise seems in order, and the question is then transformed: what are the proportionate contributions of heredity and environment in the determination of intelligence?[12] Someone formulating the issue in this way may well call himself an interactionist.

This formulation has at least two aspects that are entirely unacceptable to Piaget. First, the idea that intelligence is an "amount" that can be measured, rather than a structure which must be described and whose functioning must be understood. Second, the idea that heredity and environment are, for each individual, fixed components that determine the intellectual outcome without affecting each other, rather than vectors whose developmental significance changes incessantly, depending on the structures already achieved.

There are two features of Piaget's approach to the environment that, although not unique in Piaget, are characteristic of him and worth pointing out. The environment is not conceived as something that "happens" to the child, not a stimulus that elicits a response. Rather the child seeks out those features of the environment to which he can meaningfully respond, both by assimilating them to existing structures and by accommodating those structures to make continued assimilation possible. The initiative belongs to the child.

The ordinary conception of the environment as determining behavior rather than behavior determining the environment is an extreme expression of a commonplace adult achievement, that highly cultivated paralysis summed up in the phrase, "I only followed orders." We must admit that this is a state that can be attained, but it is not typical of childhood.

For Piaget, moreover, the environment is "nonspecific." One does not need clay balls or jars of water to learn about conservation. The materials are everywhere and unavoidable; clenching and unclenching the fist is just as good as flattening out a ball of clay. But even such simple events are so rich, so open to varied logical structurings that it is the child who sees in each experience that which he can draw upon for his growth as it must be at that moment.

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12. More precisely, what are the proportionate contributions of variations in heredity and in environment to variations in intelligence.

Piaget has sometimes labeled his position *constructivism*, to capture the sense in which the child must make and remake the basic concepts and logical thought-forms that constitute his intelligence. Piaget prefers to say that the child is inventing rather than discovering his ideas. This distinction separates him both from empiricism and from apriorism. The ideas in question do not preexist out there in the world, only awaiting their discovery by the child: each child must invent them for himself. By the same token, since the ideas have no a priori external existence, they cannot be discovered by simple exposure; rather, they must be constructed or invented by the child. Thus, Piaget's book dealing with the growth of the concepts of object, space, time and causality in the first year of life is not called *The Discovery of Reality*, but *The Construction of Reality in the Child*.

But we do not think the term *constructivism* goes far enough in characterizing Piaget's position. It is possible to believe that the child constructs his own mentality through his own activity without any preoccupation whatsoever with the development of logical structures underlying intellectual life. Indeed, this describes the romantic ideal of many progressive educators. There is something more austere in Piaget's constructivism. It goes beyond mere logicism, or the attempt to characterize each stage of development by a logical model. He proposes that the functioning of the logic of each stage determines the structure of the stage that follows. Without wanting to engage in a neologistic tournament, we suggest that the term logical determinism captures this essential aspect of Piaget's thinking. Interactionism, constructivism, logical determinism—to summarize the entirety of his position Piaget has come to call it *genetic epistemology*.

If learning were very fast and our resulting image of the world a very accurate copy of an unambiguous reality, we would all be empiricists. If there were no learning at all, whatever intelligence we possessed could be due only to preformed structures, and we would all be apriorists. The conception of learning therefore occupies a strategic role in discussions of the relation between organism and environment, and it is important to understand what Piaget has done with it. First, he has defined learning as having only a limited role within a larger process of the functioning and growth of structures. Second, he insists that learning of specific behaviors or contents can only take place within existing structures: the individual's action upon the world is itself the operation of a structure, and in the process he assimilates new information to that structure, which sometimes requires changing the structure. Third, structures grow according to laws which are not given in the behavioristic associationism of stimulus-response psychology, or in the Gestalt laws describing the direct perception of an organized world. The function of cognitive growth is not to produce schemes that are more and more veridical copies of reality, but to produce more and more powerful logical structures that permit the individual to act upon the world in more flexible and complex ways.

Having said this much, let us reexamine a problem that has suffused and troubled this whole discussion. To arrive at a comfortable alternative to preformism, is it really necessary to demonstrate empirically that Piagetian stages are affected by variations in the environment? Biologists do not need to raise some children in an oxygen-deficient environment in order to demonstrate that the blood carries oxygen all over the body, and that the complex of mechanisms for the formation of blood and assimilation of oxygen is indispensable for normal development.

Similarly, it is at least possible that there are some aspects of intellectual growth that are both indispensable for normal functioning and dependent for their development on properties of the environment that are to be found everywhere on earth. It is hard to imagine a planet that could support life that did not have permanent objects, and it is equally hard to imagine a high level of intelligent functioning (e.g., mammalian?) without the idea of the permanent object.

If you were a scientist interested in studying the growth of ideas, generally speaking it would make sense to begin by studying fundamental ideas rather than trivial ones. What is a fundamental idea? Indispensability would seem to be one of its more evident characteristics. Piaget followed an almost unique path in choosing what he hoped were fundamental concepts and operations for study, stepping outside of psychology and relying heavily on a certain philosophical tradition for guidance.[13] To the extent that he was successful in his choices, it would be difficult to demonstrate that the variables of growth he has chosen are accessible to environmental manipulation.

This is not to say that confirmed interactionists, Piaget among them, do not ultimately face the task of specifying the way in which the environment influences development. But one can imagine two quite different strategies for attacking this problem. At a primitive stage of science, techniques of measurement are crude, and it may be extremely difficult to detect variations in fundamental organs, concepts, operations: the basic requirements of development make such variations small. If we insist on searching for small and subtle effects in such fundamental variables, we must expect many failures.

An alternative strategy is to choose as objects of study things that obviously vary, even if they are not so fundamental. At first sight, this approach looks trivial (like the story of the drunk who looks for his keys under the lamp post, where the light is, rather than twenty yards away where he dropped them in the dark). Yet in biology it has yielded high rewards. Geneticists interested in mutations were willing to study any detectable mutation; one that could be produced at will by environmental manipulation would be a geneticist's dream (and would have no simple bearing on the nature-nurture dispute!) whether it affected the formation of the blood itself or only the most trivial morphological characteristic.

No psychologist worth his salt would use the preceding remarks to justify entirely abandoning the study of the interplay of organism and environment with regard to fundamental intellectual characteristics. Certainly Piaget has not done so. Only, at the present stage of scientific knowledge it may be that such study can best be pursued at

13. No one can read Piaget without thinking of Kant. He is not, of course, Kantian in his solutions, but a very considerable portion of his work has gone into studying the development of just those fundamental ideas that Kant identified and claimed were given a priori.

a theoretical level. In any event, it must be admitted that the variational method that has characterized all empirical efforts thus far, while it has produced a few interesting results in these last twenty years, has nothing staggering to show.

To take one last leaf from the biologist's notebook, what sort of approach could we hope for in studying organism-environment relationships with regard to well-protected fundamentals? A method that produced some very easily detectable effect without disturbing normal functioning or development would be ideal. The use of isotopic tracers comes to mind as a plausible analogy. Thus far, psychologists have not approached the subject in this way and have no similarly subtle tools at their disposal.

In closing this introduction we return to a point made in the Preface, the collaborative aspect of Piaget's work. From a very early age, even as an adolescent in *Le Club des Amis de la Nature*, Piaget presents the double aspect of the lonely intellect going his own way and the social being, seeking out others for real collaboration, and still others on whom to try out his ideas. His first psychological book, *Language and Thought of the Child*, was accomplished with the aid of six collaborators. The pursuit of discussion has often led to public controversy with other scientists; a few well known names that come to mind are Vygotsky, Wallon, Michotte, and Bruner—a Russian, a Frenchman, a Belgian, and an American.

As Piaget's career developed, or rather, as he constructed it, he evolved a characteristic style of working with assistants and other collaborators. This is most evident in the functioning of the *Centre International d'Epistémologie Génétique*, founded in 1955. Each year Piaget selects the topic to be investigated. Through a process of discussion, involving a large amount of give and take, the details of up to twenty specific experiments are worked out. These are discussed incessantly while being executed throughout the year by the resident members of the Centre, working in small groups which report frequently to the larger group and even more frequently to "Le Patron." At the end of the academic year, at an annual Symposium, the same work is once more presented, now in nearly finished form, and discussed with a group of invited participants. Most of these visitors are habitués, who return to Geneva periodically-not only for the Symposium, but for their own purposes, to help think through some of their own intellectual problems in fields as varied as biology, philosophy, education, physics, psychology, logic, mathematics, and the history of science.

It is this complex, multi-layered process of socialized reflection and explanation that gives the work we call Piaget's its full complexity, its somewhat involuted character, its extraordinary variety. After the Symposium, Piaget retires to a mountain retreat for a summer of writing. It is he who produces the final synthesis of all this discussion and empirical research. This too takes a double form. On the one hand, it is a factual account of the research. On the other hand, it is an exploration of ideas, a restructuring of the problematique as Piaget sees it. The research has not necessarily produced any definite answers, but it has certainly changed the questions.

## SUMMARY

There are at least three Jean Piagets. There is the austere theoretician, turning the thought of children into formal constructions of logic. There is the playful empirical scientist, who led a whole generation of psychologists into a new way of listening to children. There is the doubter, driven onward to new research by the feeling that he has not yet explained the emergence of novelty, which must lie at the core of any account of the growth of thought.

To know only one of these is not to know Piaget. One must persevere through the logical and other theoretical difficulties, listen to the children, and let some of the same questions take hold. And in reading Piaget, it is important to stop often and try to work out some of the ideas for yourself: "... real comprehension of a notion or a theory implies the reinvention of this theory by the subject" (Piaget 1973b).

# Piaget's Mission

*To struggle against war is therefore to act according to the logic of life against the logic of things, and that is the whole of morality.*
Jean Piaget. *La biologie et la guerre, 1918.*

Jean Piaget was a man with a sense of mission. There is no other way to understand his seventy years of intellectual productivity, his more than fifty books and hundreds of papers, his unflagging tour of what he called "the circle of the sciences," always searching for some way of grasping the unity of all knowledge. In this essay I want to call attention to Piaget's mission and the changes it underwent.

Piaget's work has generally been presented as a scientific theory. As such, it must be examined for its completeness, its internal coherence, its ability to generate testable hypotheses, and its ability to meet the tests. It can meet the many empirical tests it confronts either by successfully assimilating pertinent new facts or by accommodating itself to them. In the case of assimilation, scope and richness are enhanced. In the case of accommodation, the structure of the theory itself is modified.

Examining any scientific theory in this way is likely to be interesting work and, in the case of an influential theory like Piaget's, important. But that is not my aim in this essay. Rather, I hope to present Piaget's work as a set of discussions among contemporaries. This requires some consideration of how his theory grew, of what it has in common with certain other theories, and of how it may be expected to evolve if it is to meet the needs people have for an "appropriate ideology."

The issues to be dealt with include: the relation between philosophy and cognitive science, the movement between intuitive and rational thought, the connections between interest in cognitive universals and controversies about innate ideas, and the tension between beliefs in the inevitability of progress and admiration of unique creative processes. I hope the reader will forgive a few anachronisms that arise because I have sometimes put Piaget up against people active now, while most of the discussions that shaped his work came earlier.

This essay, like all my work these days, has, as an arrière pensée, the threat of nuclear war and consequent extinction of our species. Although I love to study the play and growth of ideas, such scholarly activity does sometimes seem like collective whistling in the dark. But I do not want the nuclear goblins to hide, either in the real silos or in the submarines of my mind. Only their dismantling will put my mind at rest. And so, in everything I write, I try to establish the connections between all human activity, including the most arcane science and scholarship, and the destiny we are shaping for ourselves. In Piaget's case, this is not particularly difficult, since he wrote a long prose poem in 1916 and a philosophical novel in 1918, both colored by the Swiss youth's knowledge and abhorrence of World War I and exploring the troubled question of the relation between science and morality.

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For the next twenty years or so, Piaget remained actively interested in such issues and, in his work on moral judgment, made fundamental contributions, still being elaborated and extended by others. His own later work took him in a more purely cognitive direction. If the reader is imbued with a sense of the imperial power of cognitive science, he or she may be impatient with my efforts to link up these domains. But I think it is worthwhile to think of Piaget's life as a whole, to explore the connections between the young, passionately moralizing Piaget and the progenitor and elder statesman of cognitive science.

Throughout his life, Piaget had a sense of mission. In its later and better known form, it is well captured in his phrase, "Logic is the morality of thought." But this way of putting matters evolved over the decades from a somewhat different origin.

One of the earliest expressions of Piaget's mission was the prose poem *La mission de l'idée*, written in 1915-16, when he was nineteen, and motivated in good part by reactions to *La Grande Guerre*, the terrible 1914-18 war in which almost 40 million were killed. The Idea of which Piaget sings in this long *hymn to the idea* changes form incessantly, but always progresses toward some unseen ideal. In a concluding passage extolling the unique worth and special contribution of every individual, he wrote:

> ... When the idea is reborn, every man now suffering in the shadows will find his place in the vast harmony which by its crescendo will make life grow, so high that it will see God. But the rebirth of the idea requires the help of everyone. Metaphysics is not an aristocratic art. The scientist, who finds hypotheses, must build over them a grand edifice that can contain them; the Christian, who in the depths of his heart has felt a life, must assimilate it by an interpretation which justifies it; the moral man, who wants a rule of conduct to govern his life, must construct an idea to justify it. The special mark of each man must be his idea and from these ideals, numerous as the cells, the true idea will come forth, like the soul from the body.
> Oh! that the tears shed during the war bear this beautiful fruit: the new birth of Christianity.
> For that is the mission of the Idea. (Piaget 1916)

In 1917 he wrote a long letter to the great antiwar writer, Romain Rolland, saying, "the great problem is to base morality on science" (Piaget 1966a).

In 1918 he published his philosophical novel, *Recherche*, which concludes:

> We have sought to take account of the most pressing problem posed by the war, the moral personality of societies. For it is in Humanity alone that we can commune in our diverse works: it alone will reconcile science and faith. (Piaget 1918c, 210, my translation).

Although "faith" eventually disappeared from his writings, this impassioned sense of the connection between morality and logic remained a note he could strike from time to time. But it sounded louder and more often in the first decade of his career than in the last. Moreover, there is a disparity between his experimental-clinical work with children and his theoretical writings. The former would be well characterized as an exploration in depth of "the logic of things" as understood by the growing child; exceptions to this description occur early in Piaget's career and then more or less disappear. There was a period of about two years (in the middle 1960s) when he turned the attention of his research group to children's thinking about biological matters, but relatively little of this work was ever published. Was this because the problems were intractable, or because Piaget did not persist?

In his theoretical writings matters stood quite differently. In 1965 he entirely rewrote the biological section of *The Introduction to Genetic Epistemology* (1950a) and published it as a separate book, *Biology and Knowledge* (1971). This was followed by theoretical works on genetics and evolution. Perhaps it is a judgment both on Piaget and on his readers, ourselves, that he is known (and criticized) far more for his work on the logic of things than for his thought on the logic of life.

In advancing the case for genetic epistemology, Piaget aspired to a theory of the growth of knowledge at every level: the child's intellectual development, the work of a mature scientist, and the historical progress of scientific thought. A theory making such claims inevitably becomes a candidate for the role of guide to human conduct. This is particularly true in Piaget's case, since the theory itself is built on the idea of the unity of thought and action.

Beyond the tests relevant to any scientific theory, Piaget's must stand a further test: Does it deal with human life in a way that is appropriate to our time? To put the question more sharply, the way it is now often discussed: Can such a predominantly cognitive theory of growth and development possibly be adequate, even to account for intellectual development itself? Can the issues of emotional and social life simply be "added" to the theory later on—or does their present neglect introduce fundamental distortions, making an appropriate genetic epistemology inaccessible via the path Piaget and his collaborators trod?

## GENETIC EPISTEMOLOGY AND COGNITIVE SCIENCE

Piaget's work was an early expression of what has now become a widespread, many-faceted tendency, dwelling most generally under the banner *cognitive science*. Piaget was the founder and director of the *Centre International d'Epistémologie Génétique*; similar interdisciplinary groups exist in other places. In one setting (Geneva) the focus is on child development and the history and philosophy of science; in another on linguistics and logic; in another on computer science coupled mainly with the study of adult human experts; in still another on computer science coupled mainly with the study of child cognitive development. And so on.

What these enterprises have in common is a belief that quite diverse knowing systems must share certain general properties. Since the properties are thought to be general, the search for formalisms that can cover diverse cases is taken as a *sine qua non*. The structures or procedures sought or built are entities intended to have wide applications: they are cognitive universals, powerful ideas, or generative rules. In spite of the deep differences between them, Piaget and Chomsky share an interest in the creativity of everyday life. Chomsky's grammars are finite sets of rules that can generate an infinite variety of sentences; Piaget's structures and schemata can assimilate innumerable ranges of experience, guide numberless acts.

These varied approaches have something else in common. They do not exhibit any great interest in the sort of abstractions that can be made about people doing things that are only meaningful to the experimenter. Earlier generations of psychologists watched people looking at nonsense forms, memorizing meaningless lists of nonsense syllables, or performing fragmentary reflex acts. Much of this work still goes on. Cognitive scientists, however, are, for the most part, interested in thoughts that real people think, real things they do and make. The tradition of a dual track in the human sciences goes back at least as far as Wilhelm Wundt, who traveled both tracks but, until the recent Wundt revival, was remembered only as the father of this experimental psychology of meaninglessness (See Rieber 1980). In fact, he believed that a merely experimental psychology would be sterile, and he wrote a many-volume work on *Völkerpsychologie*, a central aim of which was to understand the human mind through an examination of its works. This is a theme taken up by others in Europe over the decades, notably Piaget's friend I. Meyerson (1948), and Piaget himself, especially in his *Introduction à l'épistémologie génétique*.

It is natural that today's artificial intelligencers, aiming at simulating and eventually replacing humans in many complex functions, should study how real people do real things. I have a friend whose first postdoctoral job was a case study of the intuitive methods of a geologist, the corporate hope being a machine system that would reproduce the expert's functions and that could be manufactured in multiple copies.

But I hasten to add that interest in such cognitive case studies does not necessarily stem from the corporate productivity ethos. My own work on Charles Darwin, an elaborate reconstruction of his theoretical thinking during a two-year period, based on close examination of his notebooks, had other roots and aims (Gruber, 1981e).

A key point uniting these diverse yet similar enterprises is a simple and, to me, attractive quality: a willingness to listen, to attend to one person doing something interesting, over long periods of time if necessary. The aim is some sort of conceptual reconstruction, but the starting point is respectful attention. Piaget's first work, *The Language and Thought of the Child* (1955), begins with a long chapter based almost entirely on two six-year-old boys, each observed every day for one month in a school setting. His master work, in my opinion, is the trilogy about his own babies in the first two years of life (Piaget 1952c, 1954, 1951). Herbert Simon and his collaborators have produced an analysis of 100 pages of one person solving a problem (Newell and Simon 1972).

Max Wertheimer's seminal work, *Productive Thinking* (1945), was also an enthusiastic effort to understand and reconstruct thought processes by the examination of spontaneous productions. And in its own way, much earlier, so was Köhler's *Mentality of Apes* (1976).There were, of course, profound differences between Piaget and the Gestalt psychologists. Nevertheless, they were alike in their firm resistance to tendencies toward atomism and positivism in psychology, and in their efforts to describe psychological processes as the work of self-regulating systems. Piaget often remarked that, if he had met with Gestalt psychology a little earlier, he might have been among their ranks. For an international man of science, this was a courtly thing to say, but I think it was an exaggeration. Unlike his Gestalt friends, Piaget was never tempted to apply the metaphor of perception to thinking; perhaps he was too abstracted a man for that. Logic and a very abstract idea of embryology and growth provided him with his root metaphors.

It is probably inevitable that interest in the single case and in structural wholes should be closely coupled. But to see the person as a self-regulating system, it is also necessary to abandon the heavily interventionist strategies of most experimental psychology. The will to watch an individual performing spontaneously is not only a question of method but of basic conception.

The ideal experiment is one in which the subject successfully adjusts his or her behavior or perceptions to demands or stimuli imposed by an experimenter. In Piaget's language, this is accommodation, one half of the inseparable duo of functional invariants, assimilation and accommodation. In the other half, assimilation, the organism has the initiative, choosing which events to incorporate and into which schemata actions and experiences will be assimilated. Piaget spoke of the young child's play as "pure assimilation" and his book, *Play, Dreams and Imitation* (1951), was a pioneering study, not only of play, but of the development of the activity of play. It is of some interest that he took up this theme again with older children, paying especial attention to rule-governed games and to the child's changing conception of the sources and nature of rules (Piaget 1932).

Piaget's penchant for studying and reflecting on the nature of spontaneous activity was not restricted to those of his works specifically directed at children's play and games. Almost every experiment of the Geneva school has a play-like aspect to it, using ingenious toys and toy-like material to bring out the child's level of intellectual functioning. This was the house style, very much in evidence at the Monday meetings of the *Centre*. When an assistant brought out the material for a new study, it was likely to be some delectably puzzling object from the toyshops of Geneva, or the student's own contrivance in the same genre. There would often be a collective glow of child-like pleasure spreading around the seminar table—although some logicians managed to restrain themselves.

In spite of the austerity and logicotropism of Piaget's theory, this inventive play and accompanying glow are part and parcel of the Geneva spirit. These attributes seem to fade as the work migrates and Piaget's studies are "replicated" in this country. Although it is hard to say just how, I think the theory changes too.

It should be emphasized that Piaget's penchant for children's toys and games did not mean that he had any love for untrammeled spontaneity. On the contrary, research was conducted under conditions controlled enough to permit observation of the progression of intellectual stages in the growth of the child. Moreover, Switzerland is a very proper country. Interest lies in taming the savage mind, not in adoring it. Piaget's innovation was the idea that the child tames himself.

This carefully measured and monitored interest in spontaneous activity as the source of development probably characterizes a large sector of the cognitive sciences, certainly Minsky's and Papert's work at MIT and Simon's at Carnegie-Mellon. But there is a major qualification to be made, to which I now turn.

I have tried to indicate three broad areas of agreement among cognitive theorists. First, about structures: there is a shared belief that material of cognition consists of configurations, or self-sustaining structures, rather than atomistically conceived elements. I avoid the term "structuralism" only because that label has acquired other theoretical burdens that are outside the range of this discussion. Second, about spontaneity: these cognitive theorists tend to be interested in spontaneous activity of the subject rather than in stimulus-bound reactions. Third, about generativity: these theorists aim to account for intellectual activity and adaptation as the work of a finite, rather small number of powerful structures, with great generativity and creativity, rather than some much larger number of more limited elements. For example, with only 50,000 words and a small number of rules, an infinite number of correct sentences can be generated. Linguists who differ fiercely on the origin of the rules nevertheless agree on this property of generativity.

There is a broad but perhaps less complete agreement on a fourth area, ratiomorphism, to use Egon Brunswik's term. As he put it:

> From the dawn of science, efforts have not ceased to conceive of man as a rational being. One of the sources of this belief must be seen in the explicit or tacit realization of the fact that adjustment and the struggle for existence require some form of rebuilding of the surroundings within the organism so that orientation and anticipation can take place.
>
> For any system, such construction or extrapolation beyond its boundaries involves integrative interaction within the system. What is more, it involves the particular type of orderly interaction we find best exemplified in syllogistic reasoning or in mathematical calculation. (Brunswik 1966)

Now there are many logics, formalisms, symbol systems, programming languages, notations to which different theorists have committed themselves for awhile. But there are also some cognitive theorists who believe that it will never be possible to translate all of cognitive activity into a rational or quasi-rational form. Kenneth Hammond (1982) has made a good case for the idea that cognitive activity moves incessantly back and forth along a spectrum of possibilities ranging from intuitive to rational. It may be argued that progress consists in moving toward the rational, although complete rationality is never attainable because, as new situations relentlessly arise, they must go through long evolutions in which they are "rationalized," gradually falling under the sway of more and more ratiomorphic control systems.

But Hammond also argues (and demonstrates experimentally) that the intuitive mode is sometimes the more appropriate way of dealing with a task, in particular when no algorithm exists that would make an analytical approach more fruitful. This emphasis on voluntary selection of the cognitive mode appropriate to task requirements differs from the more ability-oriented approach of David Feldman (1980).[1] The latter argues that some individuals are constitutionally tuned to certain kinds of tasks. In spite of the difference, the underlying agreement on the issue of appropriateness should not be overlooked.

Piaget's position on this matter is not easily placed. He divided mental life into two kinds of processes, figurative and operative. Only operative structures show the stage-like progression which attaches to his name. These are the ratiomorphic aspects of cognition, but there is not one fixed logical system so much as a series of logics necessary to describe the child's thinking at successive stages. A final stage of *formal operations* is reached in adolescence. It is not specified in Piaget's theory if or how development continues after *formal operations* have been attained. As for figurative processes, although they do not develop, Piaget does not really treat them as independent systems. In the works of the Geneva school on perception, imagery, and memory, these figurative processes are depicted as always under the control of the developing operative or ratiomorphic system. This is an ambiguous position. On the one hand, there is something there that never changes. On the other, this something—perceptivity, intuition—is under the control of something that does change. I believe there is a similar ambiguity in much of Herbert Simon's work, although his concessions to the nonratiomorphic emerge only in brief asides as compared with Piaget's book-length deviations from the main track.[2]

My own position on the relation between intuition and ratiomorphic or analytic thought is akin to a more general position, to which I have been drawn, about creative thinking. The organism comprises a number of subsystems, each with its own mode of functioning, its own tempo, its own developmental rate and course. These systems are only loosely coupled. One may seem dominant at one moment, but this changes from time to time and the pattern varies from person to person. Over quite a wide range, the visual system seems to dominate other sensory systems. But anyone who has seen a foreign film with dubbed voices has experienced the auditory capture of the visual system, and anyone who has tried not to keep in step with martial music knows the power of music over muscle. Similarly, there are times when an intuitive grasp of the right answer guides our analytical work to its destination, and other times when rational analysis overpowers intuition. And there are still other times when intuition and reason simply remain at odds until some new consideration resolves the dilemma. Without this lively interplay of loosely coupled systems, our lives would be much the poorer.

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1. Howard E. Gardner takes a similar view on this point.
2. For selections and commentaries on this work, see Gruber and Vonèche, The Essential Piaget, Part VIII. *Figurative Aspects of Thought: Perception, Imagery, and Memory*.

## COGNITIVE UNIVERSALS: INNATE, TAUGHT, OR SELF-CONSTRUCTED?

As we have seen in the quotation above, Egon Brunswik took constructive processes for granted as an obvious part of any theory about knowing systems. But it is not so obvious. Theorists as diverse as J. J. Gibson and the Gestalt psychologists in perception and Chomsky in linguistics have taken positions that Piaget would characterize as entailing "structure without genesis." The classic behaviorist position, "genesis without structure" in Piaget's theoretical idiom, may be treated more briefly here, as it was quite explicitly noncognitive. Piaget described his own position as the third alternative, centering on the growth of structures.

Piaget always saw the dichotomy between nativism and empiricism as a misleading way of putting an important theoretical problem. In one view, fundamental cognitive structures are seen as *wired in*, innate. In the other, these structures are direct reflections of realities in the organism's environment. In answer to the naive empiricism of the latter position, he once wrote a paper entitled *The Myth of the Sensory Origin of Scientific Knowledge* (1977b). It is not through action or direct experimentation that we learn about the world but through reflection upon our actions. As he put it in *La mission de l'idée*, the prose poem written when he was nineteen:

> Progress springs from the brains of wise men, not from the arms of men of action. The Revolution was made in Rousseau's contemplative walks and not in meetings or uprisings in the streets. When a man of action dies, his work lives on just long enough to produce a few new men of action, paler and weaker then he. When a man of thought dies, his work sets off a thousand men of action, all armed with a new strength. (Piaget 1916, 28)

A contemplative walk, usually at least an hour, figured in Piaget's daily life, and reflectivity was an attribute written large in his theory and in his conception of human intelligence. In the passage quoted from *Mission*, there is a noticeable ambivalence toward "men of action." The writer seems pleased that the "man of thought" sets off a thousand men of action.

As his thinking on these matters developed, the point became, not to deny the importance of action, but to insist upon it as the source for and material of reflection. Moreover, in his theory of mental operations, thought and action are no longer opposed: thought is interiorized action. This said, it was at once important for Piaget to criticize the *copy theory* idea that thought is *nothing but* the image of actual motor activity. The removal of action to the plane of thought makes it capable of far greater flexibility, reversibility, and universality.

Piaget's relation to nativism is somewhat more subtle. The difficulties stem from the fact that he set himself the task of accounting for cognitive *universals*. He took his basic categories from philosophy, with a clear debt to Kant. Objects, space, time, causality, chance, number, identity: Everychild, through his spontaneous mental activity, constructs and reconstructs these concepts at increasingly mature levels (Piaget 1952c, 1954, 1952a). No intelligent being can do without these universals, and everyone must construct them for himself. It is not just an educational oddity that these fundamentals are not taught but self-constructed: it must be so. If a teacher were to undertake the task, the child could understand the lesson only by doing the mental work for himself, not simply sponging it up. In point of fact, all children in all cultures construct these categories untaught and unaided, unbeknownst to parents and teachers. It took philosophers to uncover their existence, and it was Piaget's greatest discovery that children achieve a grasp of these categories in a series of regular stages.

But it is just this universality, which seems like such a magnificent achievement for Everychild, that the nativist wants to take away from childhood, locating the discovery not in each child's intellectual growth but elsewhere, presumably in our common evolutionary past. Environments differ widely, yet children are all the same (with regard to these universals), runs the nativist argument: obviously, the developmental pathway of the intellect is innate. It is not even necessary to argue that the concepts are present at birth, although some nativists make the mistake of claiming this. It is enough to say that the developmental pathway is inborn—just as the adolescent shows the anatomical signs of puberty, he or she arrives at the stage of formal operations. Indeed, it is almost impossible to make a very good argument for the idea of conservation of matter without drawing on other concepts that must also be constructed, such as number and weight. Yet the concept of conservation of matter is acquired by about age six or seven, according to Piaget. Hence, say his adversaries, it cannot be constructed through rational processes. Since it is a universal achievement, a species-wide character as regular as the chromosome number, forty-seven, it must be an innate idea.

If Piaget had chosen to concentrate his attention on idiosyncratic ideas and individual differences in development, he might have met with less opposition to his constructivist approach. But having chosen to fight on the ground of universals, he almost appears a nativist himself!

Piaget might answer that the requirement of an argument good enough to satisfy a philosopher is too stringent. The child is shown two equal clay balls; one of them is squashed into another shape, say a pancake. The younger child thinks the amount of clay is changed by the change of shape. By the time the child is about seven or eight, he not only insists passionately that the amount of clay remains the same, he can also produce three basic justifications for his belief that amount of matter is conserved under the transformation of shape: (1) the argument from identity—nothing has been added or taken away; (2) the argument from reversibility—the flattened piece of clay can be put back into the shape of a ball and will then be the same as the other ball once more; (3) the argument from compensation—true, it takes up a larger area, but it is thinner. From these arguments together flows a sense of the necessity of conservation. Not watertight, but not bad.

The nativist might counter that there is nothing necessary about the idea of necessity. If that idea is a universal response to the constellation of experiences just described, then that response, that is, the idea of necessity, precisely because it is not a logical conclusion, must be an innate idea. Piaget's reply could easily be, "Not at all. Just read my works on the growth of the child's idea of causality. You will see that the younger child has no such notions of necessary connection or causality. These, too, must be constructed."

I think we are dealing with two different meanings of *innate*. In Definition 1, *innate* means gene-controlled development. The key point is that the course of development is decided by the genetic make-up of the individual. In Definition 2, *innate* means the inevitable developmental resultant of the total set of factors comprising and confronting the organism. In this sense, we are speaking about determinism in general. Piaget could subscribe to the second meaning, with the additional point that his theory involves what I have called "logical determinism." For the universals in question, there is only one developmental pathway possible, because each step of restructuration prepares the way for the next. When a certain structure is in place, new forms of activity—both physical and mental—become possible, and the next step can be taken.

Then what is the key difference between Piaget and his critics? Activity. Piaget insists that the child's own activity is the motor of development.[3] Schemata of action and experience are used repeatedly by the child; small variations occur and are incorporated into the schema; thus it develops.

But would activity in any environment lead to the same cognitive universals? Imagine a world in which everything is fluid: the baby moves his hand in front of his face repeatedly; the first time it appears much like a hand, the next time like an ocean wave (or what would seem an ocean wave to me), the next time like the smell of milk. Would the idea of object permanence (in our world acquired in the first twenty-four months of life) ever emerge in such a world? If objects do not retain their identities, can stable words ever come to stand for them, can language occur? If Piaget were to answer, yes, only activity is necessary, it would imply that object permanence is an innate idea. But I believe Piaget would say that organized, adaptive beings could not evolve in such a world; intellectual development depends on the organisms' interaction with the world; cognitive universals occur because certain properties of the world are universal, and in such a world our kind of intelligence is adaptive. Although I do not claim that this particular discussion ever took place,[4] I am sure that, in spite of certain appearances, Piaget was not a nativist but a confirmed interactionist-constructionist-logical determinist.

To all this it should be added that this form of the nativism-constructivism debate has nothing to do with the controversy about the role of heredity and environment in determining IQ. Both a nativist and a constructivist can be completely egalitarian: with regard to cognitive universals, everyone is equal.

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3. This theme of activity is most fully developed in Piaget's *Origins of Intelligence*. Although it is central to his theory, it was never investigated very much in empirical research conducted in Geneva.
4. But very similar ones did. See Piattelli-Palmarini (1980) for a full and fascinating account of this confrontation between the two men and their "teams" at the Abbaye de Royaumont near Paris in 1975.

## GENETIC EPISTEMOLOGY, PROGRESS AND CREATIVITY

As we have seen, Piaget's constructivist logical determinism gives at least the strong appearance of nativism because of its preoccupation with cognitive universals. But we should be clear on one crucial point. What is determined in this way is not a static set of attributes but a set of developmental pathways.

This position is intimately connected with a certain view of the idea of progress. Piaget's theory, like Erikson's and Freud's, is a single-pathway theory. Development is construed as progress along the given pathway. Who could deny the value placed by Freudian psychoanalysis on movement toward mature, successful genitality, or by Erikson on movement toward intimacy, generativity, and integrity? Similarly, Piaget and his collaborator, Bärbel Inhelder, spoke of "formal operations as a final form of equilibrium in mental operations" (Inhelder and Piaget 1958, 329) and as "the inevitable result of all earlier mental development" (p. 331).

So development is not only logically determined, it is progressive, and its progress is confined to a single path. Piaget does not see this movement as wired-in but as the result of the interplay of complex forces. Borrowing the idea of *homeorrhesis* from the British biologist Conrad Waddington, he argued that development travels, as it were, down a sloping valley in the epigenetic landscape. If some force produces a deviation, the sides of the valley operate as constraints, and the developing individual is brought back to the standard pathway. Thus, just as homeostatic mechanisms maintain the value of physiological variables (such as body temperature) at an optimal value, *homeorrhesis* keeps cognitive development on its optimal course.

There is an important difference between Piaget and Waddington on this point. Waddington's epigenetic landscape (1957) comprised more than one "valley"—a large enough deviation might sidetrack the developing organism over a crest and down into another valley (see also Jantsch and Waddington 1976). Indeed, he performed experiments to demonstrate the possibility of more than one developmental story. Piaget might have answered Waddington (they were good friends), true, but you choose variables such as insect wing structure, where there is room for more than one adaptive possibility. I have been dealing with universals where there is no such room. Can you really imagine a highly intelligent organism that has no idea of object permanence, causality, time, etc.?

Piaget's ideas about stage-wise progressive development have been applied to a number of issues ranging beyond the growth of intellect in the individual. This wide approach is one that Piaget himself undertook in his monumental three-volume *Introduction a l'épistémologie génétique* (1950a), which covered the history of mathematics and physics, biology, sociology, and psychology. Suzi Gablik (1977) and Herbert Read (1965) have each applied the same template to different aspects of art history. Recently, the historian of science Arthur I. Miller (personal communication) has used a combination of Piagetian and Gestalt ideas to account for the modern history of physics—dealing on the one hand with Einstein's individual thought processes and on the other with the rise of quantum theory. Mel Feffer (1982) has applied a similar theoretical blend to the field of personality development.

One of the most interesting and promising efforts in this genre is the work of two anthropologists, Sue T. Parker and Kathleen R. Gibson, in an essay, *A Developmental Model for the Evolution of Language and Intelligence in Early Hominids*. They try to show that

> ... the common ancestor of the great apes and man displayed rudimentary forms of late sensorimotor and early preoperational intelligence similar to that of one- to four-year-old children ... The descendants of the first hominid, displayed intuitive intelligence, similar to that of four- to seven-year-old children ... The comparative developmental and paleontological data are consistent with the hypothesis that the stages of development of intelligence and language and their neural substrates in our species recapitulate the stages of their evolution. (Parker and Gibson 1979, 380)

Their argument is framed in very much the style of Piaget's logical determinism, based on what Stephen Jay Gould (1977) calls the "principle of terminal addition." As they develop it, this principle includes the notion that earlier stages prepare the way for later ones, and that the evolutionary trend is toward optimization of intellectual faculties; in other words, a version of Piaget's one-track, logical-determinist theory. To be sure, Parker and Gibson are not strict determinists. They recognize that some of our ancestors evolved in different directions, and that Darwinian evolution is a chancy process. But the premise underlying Piaget's and their argument is this: if higher intelligence was to develop optimally, the path it did follow (as they have reconstructed it) was the only one possible.

Criticisms of such optimization models for complex systems have come from at least three major quarters. Herbert Simon (1969) has argued that intelligent systems "satisfice" rather than optimize; in other words, it is enough that a way is found that works; once it is found, it is implemented; the fact of implementation changes the circumstances under which the future unfolds; ergo, there is no predetermined optimum. Stephen Jay Gould and Richard Lewontin (1979) have advanced a similar argument about the course of organic evolution, and used it to good effect in their critique of sociobiology. Neither of these approaches is intended to preclude the idea of progress, so long as it is construed in nonrestrictive, non-deterministic terms. Thomas Kuhn (1962), on the other hand, regards progress as definable only within scientific paradigms; when a paradigm falls, the rules change. Since paradigms always rise and fall, there cannot be meaningful talk of progress.

In this dialogue, then, Piaget comes off as a *progressionist*. He expressed this idea repeatedly in *La mission de l'idee*. In that prose poem every individual was sanctified in his uniqueness: "The special mark of each man must be his idea and from these ideals, numerous as the cells, the true idea will come forth, like the soul from the body" (Piaget 1916, 37).

Although Piaget as a youth sang of each person's unique value, he said little of this later on.

The relation between unique and universal has been all too little explored. One notable exception is David Feldman's book, *Beyond Universals*. Granting, grosso modo, Piaget's picture of the sequence of developmental stages, Feldman suggests that every universal must first be invented, and in that first moment it is unique. How and why, of all the unique events, experiences, thoughts, do some move along the road to universality? This change may really reflect a change in the world, in the environment (including the intellectual milieu) in which ideas occur. It is in the world that ideas move through stages, not in the person.

Taking a different tack, the universals of Piaget's theory can be thought of as a relatively few broad cognitive structures. In achieving them, there is a much wider variety of strategies and procedures available to the child. This means that even the one-track developmental sequence of Piaget's logical determinism comprises a large number of pathways that have hitherto remained hidden. In Geneva today, there are several investigators delving into the relations among these highways and byways of thought (see for example Inhelder and Piaget 1980; Gillièron 1973).

My own research and writing has for some time been centered on the creative process. I have been interested in the unique rather than the universal, leading me sometimes to speak disparagingly of one-track developmental theories such as Piaget's. This has struck me as anomalous, in light of my long association with Piaget, and my feeling that I have learned so much from him. After all, the single-pathway image is not a minor aspect of Piaget's work.

It is only in the course of writing this essay that I have recognized another road the argument, stemming from this tension between unique and universal, might take. Instead of rejecting Piaget's logical-determinist, one-track theory, we might simply insist that this particular developmental pathway is imposed by the constraints of the world we live in. That being the case, it is a very great advantage that the cognitive universals are constructed by the person rather than wired-in. This long history of self-construction means that, in accomplishing these necessary universals through his own activity and reflection, the maturing person is becoming the kind of person who can reflect and construct. This means a person who can extend these activities to domains in which wide individual differences, idiosyncratic and unique creative acts, are possible.

In fact, Piaget's way of thought bespoke this connection between the child's progress toward universal cognitive structures and the scientist's creative thought. In a late summary of his position he wrote, "Remember also that each time one prematurely teaches a child something he could have discovered for himself, that child is kept from inventing it and consequently from understanding it completely." (Piaget 1970a, vol. 1, 715). For Piaget, the child was very much a small scientist, or perhaps a great one, for the discoveries of childhood are most fundamental.

In the same essay he wrote also, "There can be no theoretical discontinuity between thought as it appears in children and adult scientific thinking; this is the reason for our extension of developmental psychology to genetic epistemology" (p.706). An example of this connection that has interested me is the sequelae, among adult scientists, to the child's construction of the idea of conservation of matter under transformations of shape. It was not until the late eighteenth century that Lavoisier established the conservation of matter under chemical transformations. Moreover, the adult scientist can use the abstract idea of invariance as a heuristic to solve problems. For example, William Harvey measured the rate of flow of blood past a given point in the circulatory system and found that the total amount passing the point per hour far outweighed the total weight of the body; reasoning that the body could not produce so much blood every hour, he concluded that there must be a return route and that the blood must circulate in a closed loop. Thus he used an idea about conservation of weight to guide a physiological inquiry.

In the domain of social thought Piaget has not been so ready to extend his ideas of development into the upper reaches of abstraction. In research on moral thought it remained for Kohlberg to take this step. In the summary quoted above, Piaget gave a peculiarly truncated account of the role of social experience in cognitive development: "... the very fact that the stages [of intellectual growth] follow the same sequential order in any environment is enough to show that the social environment cannot account for everything. This constant order of succession cannot be ascribed to the environment" (p.721). He might have taken the same facts and argued that, just as the physical world has its constants, so has society; the environment always matters; interaction of organism and environment is the indispensable motor of development. He certainly wrote in this vein at other times, as is admirably documented by Kitchener, but I believe he was generally prone to pay far less attention to the social world than to the physical.

It might be argued that he wrote several seminal works on aspects of mind in society: *Language and Thought of The Child* (1955), *Play, Dreams, and Imitation* (1951), and *The Moral Judgment of the Child* (Piaget 1932)—as well as his never-translated *Etudes sociologiques* (1965) (which appeared also in Volume III of *Introduction à l'Epistémologie génétique*). Is it not unfair to criticize him for neglect of social life? But there are two points that weigh against this argument. First, *on balance*, bearing in mind the total volume of his work, he wrote relatively little in this field. Second, not a single annual symposium in the twenty-five-year series of the *Centre International d'Epistemologie Génétique* was devoted to these questions.

I believe Piaget is correctly perceived as mainly preoccupied with asocial aspects of genetic epistemology. However, when he did write of social factors in intellectual development he was quite trenchant:

> The human being is immersed right from birth in a social environment which affects him just as much as his physical environment. Society, even more, in a sense, than the physical environment, changes the very structure of the individual, because it not only compels him to recognize facts, but also provides

> him with a ready-made system of signs, which modify his thought; it presents him with new values and it imposes on him an infinite series of obligations. (Piaget 1950b, 156)[5]

On a certain cognitive plane, mental operations are the same, or at least similar, whether their "objects" are things or persons. But social objects—persons—evoke powerful emotions, so that for most people thinking is organized around persons and social values, not around inanimate objects. To treat these domains as equivalent must stem from a great underestimation of affective life. A theory that tacks on affectivity, a little reluctantly, to cognitive life is almost bound to pay short shrift to "social factors."

There are, then, an interrelated group of areas to which Piaget gave relatively little attention: (1) emotional life; (2) action (it is true he wrote of activity as the source of thought, but he gave little attention to action itself); (3) social factors. In none of these areas was he silent, and what he wrote was interesting. Still, the relative balance of the factors entering into a theory is an intrinsic part of its meaning.

One of his last great syntheses was *Biology and Knowledge* (1971). I had the privilege of participating in a special discussion group ("le petit Centre") that explored with him issues in contemporary biology and in the history of biology, in preparation for his writing that book. Only one or two pages here and there are devoted to social factors. And their main point is simply to equate the latter, in their logical import, with other factors regulating intellectual growth.

In spite of his depth and sweep and intellectual daring, Piaget does not provide us with the epistemology we need today. As I suggested at the outset, today we need a theory of knowledge that does not sever affect, cognition, and society—a theory that strengthens their interconnections to the point where love of truth and love of humanity are seen as one. Such an epistemology would be closer to Piaget's youthful mission, and might be the appropriate ideology we need.

In 1918 Piaget wrote an essay, *La Biologie et la Guerre*. His conclusion is an appropriate one for me now:

> I will stop here. I have said enough to make it understood that, the more one examines the mechanism of life, the more one discovers that love and altruism—that is, the negation of war—are inherent in the nature of living beings. Only later complications due to environmental inertia, and thus, competition, force living creatures to a restricted assimilation, that is, egoism, stupidity, struggle, and, in the human species, war. To struggle against war is therefore to act according to the logic of life against the logic of things, and that is the whole of morality. (Piaget 1918a)

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5. R. F. Kitchener of Colorado State University has written an illuminating paper on *Piaget's Social Psychology* (1985).

# WHICH WAY IS UP?

## *A Developmental Question*

### DEVELOPMENTAL THEORY AND THE IDEA OF PROGRESS

The idea of progress is implicit in almost all developmental thought. But it is not often examined very closely by developmental psychologists. It contains many puzzles, of which I will mention only a few.

Thomas Kuhn (1962) argued that, although there is a sort of progress in actualizing the potentialities of a paradigm, when a paradigm shift occurs we cannot speak of progress. The identification of problems changes, criteria of solution change, and almost everything else. When a revolution has occurred, we can say that the intellectual situation is different, but there is no communication possible across the historical barrier that separates the old from the new paradigms. Hence there is no scientifically valid means by which these incommensurables can evaluate each other.

And yet, if we step outside the framework of pure science and look at that whole endeavor from the perspective of the practical control of nature, it seems reasonably clear that there has been directional change, progress of a sort that can be in good part attributed to the alliance of science and technology. Human longevity has increased dramatically, bridges can be built much longer, and the world circumnavigated more quickly—in about ninety minutes if we include travel by satellite.

Still, matters are not so simple. The doubter would agree with all of the above but might add: Increased longevity has meant a threatening population explosion; better roads and bridges have facilitated the worldwide pollution caused by automotive travel; and satellite technology is the same as is required for delivery of the nuclear weapons that may destroy all life on earth. So stepping outside science for an external criterion of progress produces an ambiguous result. Only if a profoundly new equilibrium can be found between technological process and social control will our descendants be able to look back in admiration on our "progress."

At the level of individual development matters are not much clearer. Newton may have been alluding to a kind of within-paradigm progress when he said, "If I have seen further it is because I stood on the shoulders of giants."[1] A college physics student today standing on Newton's shoulders can see further still: His individual knowledge has progressed beyond Newton's. But it is not so easy to say whether or

1. For interesting discussions of this famous remark of Newton's see Merton (1965) and Christianson (1984).

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not this constitutes individual progress. Even an "A" student may not actually have a more powerful mind than Newton's! But, if we say that, are we admitting that the mastery of powerful ideas does not make a mind powerful?

A further dilemma arises in evaluating individual intellectual development. Suppose the very process of cognitive growth leads the individual further away from the humane values needed to control the technical fruits of thought. Would we happily call that progress? Instead, we protect ourselves from this dilemma by conceptually separating issues: We make a sharp distinction between cognitive and moral development. In other words, we absolve the individual of responsibility for his work. In thus exalting the intellect we emasculate the person. Such postures have led to deep crises in psychology about the relation between values and cognition, about the adaptive nature of thought.

So the progress we can speak of with some confidence has led to a widening gulf between technological power and human values, and between the sum of human knowledge and the individual human intellect. Only if we accept the single-valued idea of power, both intellectual and technological, can we speak with any certainty of criteria for progress and use comfortably the vocabulary of "higher" education, "advanced" stages of development.

In thinking about these dilemmas I once wrote a poem for my nine-year-old daughter.

*Upoem*
"Which way is Up?" seems an odd sort of query.
"Toward the sky," says one famous theory.
"Over your head," runs another idea.
The difference between them is not always clear.
But if you lie down you may have to choose:
Is Up away from the earth, or away from your shoes?
Do we really know which way is Up?

## SPECIAL PROBLEMS IN EXTENDING DEVELOPMENTAL THEORY TO ADULT DEVELOPMENT

Existing developmental theory is framed around the idea of cognitive and affective universals. Although there are serious problems, this works well enough in dealing with child development. The intrauterine environment is remarkably stable; and within each society, a reasonably stable environment is provided for every child, especially in the form of developmental tasks which must be mastered one way or another. But as maturity approaches, the individual is required to differentiate himself from this stable environment, build his and her own nest, find a suitable terrain, carve out an ecological niche: In an exogamous world, everyone must adapt to meet the new conditions imposed by moving to the next village.

The idea of universal developmental progress toward a number of broad species-specific attainments depends either on a noninteractionist theoretical position (i.e., hereditary dispositions) or on an interactionist position with the assumption of a stable environment. If we reject the noninteractionist position, which almost all developmentalists certainly do, then the conditions of a rapidly changing world impose on us the theoretical task of reconsidering our theories in the light of the world in which development actually takes place.

These problems are severe enough when we consider individuals who stay fairly close to their societal norms. They become almost overwhelming when we extend our scope to consider extraordinary individuals. For then we see another facet of most developmental research: It is centered on the typical performance rather than the optimal development of those studied. If we are seriously interested in how developmental innovations come about, we need to know how the extraordinary individual develops and functions. To be sure, since we remain interested in the whole species, we need also to be interested in the diffusion of novelty. Most likely, invention and diffusion are quite different processes, but up to now we have no knowledge of how they interact in psychological development, because the question has hardly been raised. While this problem is important even in child development, it becomes acute in understanding young adult development in a changing world, one requiring new adaptations for survival.

## ALTERNATIVE APPROACHES TO UNILINEAR UNIVERSALISM

Alternatives to the fixation on the universal and the typical have been proposed and do guide some research. David Feldman's (1980) seminal book, *Beyond Universals in Cognitive Development*, sets out the claim that psychologists must attend to the two-way relation between the unique and the universal, each setting the stage for the other. Howard Gardner's (1983) *Frames of Mind: The Theory of Multiple Intelligences* takes a less radical stance, since he only proposes about seven major types of intelligence, each with its distinct neurological substrate and each with its particular requirements for optimal development.

Relatively minor modifications of conventional research designs can sometimes produce dramatic effects on level of performance achieved. Harlow's pioneering work on learning sets remains an important example of a change in our conception of cognitive capacity produced by a change in experimental design. Elsewhere (Gruber, 1982c), I have summarized more recent efforts in the same direction by Ericsson, Chase and Faloon (1980), Kuhn and Ho (1980), and Spelke, Hirst and Neisser (1976). These all involve massive amounts of well thought out training. But even as simple a change as allowing a child or adolescent to perform a formal-operations task (e.g., the bending reds test or the idea of isolation of variables) twice, with an interval of one week but no intervening instruction, can produce a sizable shift in performance (Stone and Day 1980).

In their seminal work, *Plans and the Structure of Behavior*, Miller, Galanter, and Pribram (1960) called the attention of a wide audience of cognitive psychologists to the facts of mnemonic processing. Half a century of experimental research on memory, with meaningless materials and subjects hamstrung by cramping experimental procedures, had produced a picture of human memory as slow, limited, and laborious (e.g., ten trials to learn a list of ten items). Once the subject is invited to use his memory imaginatively, it is hard to find the limits of this capacity (e.g., one trial to learn a list of 1,000 items). The authors concluded, "Let us imagine that this hooking operation is available and that it is as cheap and easy as it would have to be to support the discursive human intellect. What do we do with it? Given that we can nail two boards together, how do we build a house?" (p. 138).

Since 1960 when those words appeared, there have been hundreds of experiments on mnemonic processing, in the main confirming the same line of thought. We know a lot more about memory, but we still know little about the psychology of building a house, mainly because we as a discipline have not looked. Yet, if we are interested in adult cognitive development, should our main concern not be with the way in which part-processes are integrated into larger functional units with productive consequences?

Are there any knowable ultimate limits on human performance? Psychologists might have a look at the history of athletic records. Between 1864 and 1981, the world's record for the mile run declined steadily from 4:56 seconds (Charles Lawes) to 3:47.33 seconds (Sebastian Coe). No doubt, at each stage there was intense debate as to whether the record, or some other standard, could ever be broken. When I was a boy, Glenn Cunningham was a heroic figure, but he never ran a four-minute mile, and we very much doubted whether any human ever would.

The plain fact is that psychologists do not understand cognitive processes well enough to know anything at all about human limitations. By the same token, we are ignorant of the meaning of any progressive change we observe: is it a small increment with untold progress still lying before us? Or is it near the ultimate of what we can expect—for that individual, that age group, that type, the species?

As applied to adolescent and young adult development, this ignorance of process has led to a theoretical situation in which it is fair to argue any of the following positions about formal operations: (1) they are attained by all normal adults and represent the final stage of cognitive development; (2) they are attained by only some adults and represent the final stage of cognitive development; (3) there are stages beyond formal operations, such as dialectical operations; (4) the whole concept of unilinear stagewise development is questionable. In Geneva, one important reaction to this crisis of understanding has been to set aside study of developmental progress for the time being in favor of a more process-oriented approach. Thus, in Inhelder's *Strategies Group* very small numbers of subjects, often adults, are studied very intensely in problem-solving situations. Cybernetic and dialectical ideas are being blended with Piagetian structuralism. Although they work with unselected subjects (that is, not individuals selected for extraordinary attainments), the style of their work comes very close to the *evolving systems approach* that has guided my work and my collaborators'. The key points of similarity are first that one goes deeply enough into a problem to really understand the structure of the situation confronting the subject; second, that one works intensively enough with the subject over long enough periods to watch a cognitive process unfolding, a struggle going on; third, that the analysis of results does not focus on the number or time of solutions, but on the changing configuration of the ongoing set of processes.

A key difference is that the focus of attention in the *strategies group*—as in most problem-solving research—is on the activities of subjects working for an hour or so on a single task provided by the experimenter, and chosen to be unlike the things the subject has previously mastered. For all its virtues, this kind of work cannot possibly tell us how the young adult becomes a person confronting situations that engage his or her whole spirit and energies, who can orchestrate multiple activities in a workable life, and synthesize larger wholes to make coherent products.

To be sure, many adults do not have a full opportunity for such a self-actualizing pattern of existence. Alienated and infantilized by oppressive conditions of life, they would not be good subjects for studying the "upper" limits of human potential. That is why, difficult as it may be, it is important for us to keep as our benchmark well-developed people doing creative work.

## WHY WE NEED TO STUDY CREATIVE WORK

Perhaps we need and will eventually be able to elaborate a new kind of stage-oriented developmental psychology, one in which development moves in a number of alternative directions. This idea of multi-directional development fits in with the theory of homeorrhesis proposed by Waddington (1957), the geneticist-embryologist: there are strong environmental forces maintaining the individual in one course of development. But if a strong enough deviating force is introduced he may be pushed over into another valley, or creode, of the "epigenetic landscape," and follow quite a different path. Michael Armstrong's (1980) book, *Closely Observed Children*, is one example of the kind of attention to the individual subject that we would have to give in our research to detect and study such developmental differences.

Piaget (1971) was interested in Waddington's ideas and cited them often. But he was too preoccupied with elaborating a model of "logical determinism" (see Gruber and Vonèche 1977) and applying it to human cognitive development to pursue the possibility of divergent development implicit in Waddington's ideas. Instead, he exploited the ideas of *homeorrhesis* and creode to explain the universal features of cognitive development that interested him. In my opinion this was a good strategy for guiding Piaget in his chosen work, sketching out the main lines of intellectual development and pioneering the search for models of thought. But we will never get very far beyond Piaget simply by extending his approach to one or two more stages. Instead we must understand the process of change. This requires a focus on the individual. And this methodological decision leads us in turn to look at creative individuals, for it is in them that we see the processes of change and innovation clearly displayed in adult development.

The idea of multiple developmental pathways meshes well with Darwin's fundamental metaphor and underlying model, his image of the "irregularly branching tree of nature" (Gruber 1978a, See 241). Each evolutionary branching point results from an unrepeatable encounter between organism and environment, unrepeatable because neither will ever be the same again. The general fact of evolutionary divergence is not happenstance but a necessary consequence of combining natural selection and the branching model. In human history as we have known it thus far, the same sort of idea applies with even greater force to the continuous production of cultural diversity.

Thus one reason for studying creative individuals stems directly from our interest in understanding the behavior of our species as a whole. Extraordinary individuals pioneer, innovate. They create an environment in which their contemporaries and descendants can emulate or reject what has been put before them. The processes of choice and reproduction are distinct from the processes of production of novelty. Together, they form a whole in which continuing adaptation can be understood.

It is sometimes argued that the child, too, is creative, constantly constructing his own intelligence. In a sense, this is true. But there are at least two profound differences between child development and creative work. First, child development moves the individual toward pre-existing norms; this point bears not only on the result but on the process of intellectual growth, as evidenced in the recent literature on imitation and modelling. Clearly, creative work moves the individual away from such norms.

Second, creative work is characterized by long term goals consciously pursued by a subject well aware of his unusual relation with the world. In 1831, age twenty-two, just before setting out on the *Beagle* voyage, Darwin's creative aspirations were so vague and unexpressed that his father expressed the fear that it would be "disreputable to [his] character as a Clergyman hereafter." Dr. Robert Darwin was reassured by Charles' uncle, Josiah Wedgwood, who wrote to him that "the pursuit of Natural History, though certainly not professional, is very suitable to a clergyman." The idea that he would return home to find a "quiet country parsonage" remained with Darwin for some time. It was in the work he did on the five-year voyage that Darwin reshaped his goals.[2]

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2. The story of Darwin's appointment to the *Beagle* is recounted in *The Life and Letters of Charles Darwin*, edited by his son Francis Darwin, 3 vols. London: John Murray, 1888. see especially vol. 1, chapter 5. The quotations I have given, together with Darwin's early entries in the *Beagle* Diary, make clear that although he intended to go into the clergy, natural history formed an important part of his plans. Within that vast domain his plans were entirely vague.

## SCRIBBLES IN THE ATTIC

There is a practical reason for centering much of our discussion on the growth of thought of creative people. They leave better traces. Every child produces many, many drawings and other creative acts. In a fortunate enough family these may make their way to the attic, there to lie for a generation or so, and then to be discarded with a sigh on moving day. But if in the meanwhile the child has become Picasso, his childhood leavings will be spared and treasured. They are there for us to study.

There is another facet to the matter of tracks. In our work on the creative process we have seen over and over that the making and leaving of tracks—preliminary sketches, countless revisions, early notebooks, variations on a theme, and so on—is part and parcel of the process itself. This is a kind of activity characteristic of people doing creative work. Wittingly or not, they create the conditions under which we can study their development.

Finally, of course, the creative person does not merely make one work and then stop. His intention is to lead a creative life, to make a series of works, an oeuvre. Sometimes, it is the cumulative impact of his work that we feel; in other cases that accumulation provides the setting for the one masterpiece that marks the person off for all to see.

Where the traces exist, there is nothing to stop us from applying the same methods to the study of less extraordinary people. It may even turn out that as a field of scientific inquiry, ordinary people are more intriguing than extraordinary ones. In any event, as psychologists we hardly have the luxury of such choices. In the long run we are responsible for understanding the interplay between stable adaptations and innovations, the spectrum from the universal to the unique.

## SOME POSSIBLE MODELS OF INDIVIDUALIZATION IN DEVELOPMENT

By now it may seem to the reader as though I am slipping from my earlier agnostic position about developmental progress into a more hopeful, some might even say, prayerful attitude toward creativity. Of course I am. I hope, however, that what is gained from the discussion thus far is a more questioning attitude toward the idea of unilinear developmental progress through a single set of stages. Possible models of development include the following:

- *Linear model with alternative pathways to each developmental way station.* It should be noted that the precise nature of each point of arrival would vary somewhat, depending on the pathways taken.
- *Radial model*, in which a number of developmental lines move out from a common center. The common center might be construed as some basic set of achievements which provide the point of departure for later differentiation along a number of lines, such as Gardner's frames of mind.

- *Irregularly branching model*. Even granting some common set of achievements as a base line, subsequent departures from it may be quite haphazard, depending on innumerable organism-environment interactions in an irreversibly evolving historical context.

The models are not necessarily mutually exclusive. Historically, they may have been developed as alternatives to each other. But each may capture certain parts of a developmental cycle.

Figure 1. shows one possible way of exploiting the merits of all four models that have been discussed here. The strict linear model is reasonably close to the major developmental theories that make no theoretical effort to represent individuation. It is probably a good representation of prenatal development; obviously, some would argue for its pertinence much later on. The linear model with alternative pathways is similar to an idea recently expressed by Fischer and Bullock (1984); the radial model, depicting the emergence of cognitive types, corresponds moderately well to Gardner's (1983) recent proposal, although he did not locate the appearance of his proposed types somewhere in a developmental sequence. The irregularly branching model is, of course, a representation of my own leitmotif about the uniqueness of each person. Stringing the four together in this way and referring to them as phases is meant to suggest that each may capture a part of a complex picture of increasing differentiation and individuation.

This picture is historically bounded in two ways. First, it is based on psychological knowledge and reflection as of now. Perhaps, for example, if we looked more closely at infant or even fetal development, we would not be tempted to apply the unilinear model at all. For the time being, however, it should be admitted that there are some marvelous regularities in prenatal human growth.

Second, the d-phase of irregular branching and almost unbounded individuation in at least some aspects of development, can probably only occur under certain societal conditions. We can imagine societies or communities so cramped that only very narrowly constrained channels become actualized.

In any event, every model of development that emphasizes the divergent variability of human development must also build in some constraints. People who are quite different must be able to understand each other, cooperate, marry, teach each other, and so on. Artist and scientist can draw from each other without being alike. The artist-poet William Blake had Newton in mind when he wrote the lines

> To see a World in a Grain of Sand
> And a Heaven in Wild Flower,
> Hold Infinity in the palm of your hand
> And eternity in an hour.[3]

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3. These are the first four lines of William Blake's poem *Auguries of Innocence*.

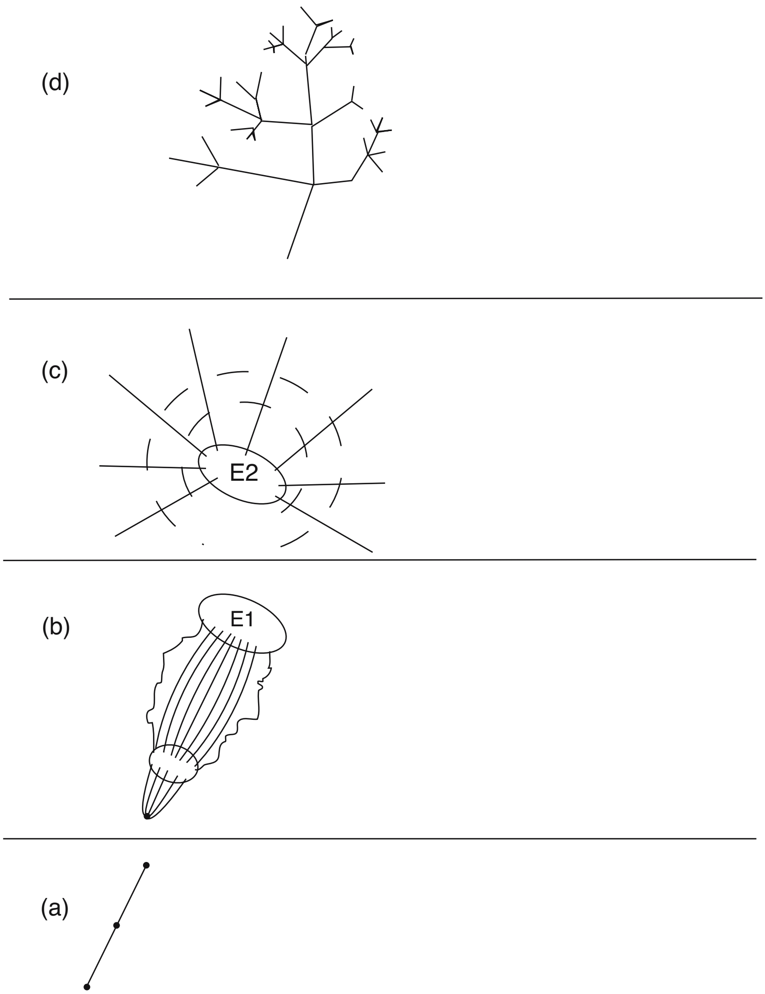


*Figure 1.* Phase a. Precise stages in embryonic development, repeated by every individual. Phase b. Developmental way stations with multiple pathways from one to another, and some variability at each point of arrival. Phase c. Radiation of types from some common, shared point of departure. Phase d. Irregular branching as individualization continues. The ellipses E1 and E2 are really the same phase, with separated projections of it for pictorial convenience in showing differentiated inputs and radiating outputs.

He caught something about Newton, whom he saw as the rationalist extraordinary, whom in some moods Blake exalted and in others detested as the arch enemy. That they could have shared their experience of the universe is shown in Newton's own remark, and its likeness to Blake's lines:

> I do not know what I may appear to the world; but to myself I seem to have been only like a boy, playing on the sea shore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.[4]

Frank Manuel has suggested that this remark by Newton, made in his old age, may have been false modesty rather than authentic humility in front of nature. But I think it penetrates deeply into our questioning about human progress. "Boy" or not, Newton suggests that we can make only finite progress, but the "ocean of truth" is infinite. Making such progress as we can depends on carving out a finite universe of action, thought, and discourse within which to work. Doing creative work requires both a sense of mastery of what we can do and a sense of awe of what we cannot. Blake and Newton were a century apart, and one spoke the language of mathematics while the other detested it. But on the marriage of mastery and awe they could agree.

## THE CURRENT STATE OF CREATIVITY RESEARCH

Let us for a while at least presuppose (1) that the study of human creative work could in principle illuminate our discussions of the "upper" levels of development and (2) that there is sufficient connection between creative work and ordinary human functioning that the study of each could illuminate the other. I say "could" deliberately, for I believe that in our present state of knowledge we would be doing very well if we could understand even a single person doing creative work. In what follows, I first very briefly sketch the "evolving systems approach" to creative work, and then survey a number of contradictions and gaps in our present understanding.

## THE EVOLVING SYSTEMS APPROACH

The *evolving systems approach* to creative work grew out of my reconstruction of Darwin's thought processes during the period in which he was searching for and elaborating the theory of evolution through natural selection. The study of Darwin's notebooks provided a clear occasion for the formulation of an approach toward understanding:

- The evolving organization of knowledge; the growth of a theoretical structure for synthesizing a very wide range of biological and geological knowledge and thought.

4. Quoted in many places. I take it from F. E. Manuel, *A Portrait of Isaac Newton*. Washington, D.C.: New Republic Books, 1979.

• The emergence of an organization of purpose; the continuing development and modification of Darwin's scientific enterprises, their interplay, and their role in regulating his life work.
• The organization of affect; the early growth of his cathexis with nature, the role of values and emotion in governing his work and his relations with others—scientists, other intellectuals, pigeon keepers, family members, etc.

This study formed the basis for my book, *Darwin on Man: a Psychological Study of Scientific Creativity* (1981e), and from that book emerged the *evolving systems approach*. We say "approach" only because the word "theory" seems a little pretentious for the present state of our understanding. Although in our work thus far we have concentrated on individual creative work, we are mindful of the social context in which such work goes on—both the general social context and the social organization of the work itself. Unfortunately, there has been very little serious study of the process of collaboration. Much of the sociologically oriented research that might have gone in that direction has instead been concerned to deny the reality of individual creative work. One might as well deny the reality of the individual organism because it exists in a milieu, mates with others, and rears its young.

In the *evolving systems approach* as we conceive it, it is not necessary to suppose that we are looking for some set of traits shared by all people doing creative work, or by some subset, such as artists or scientists, or cubists or particle physicists. We choose a creative person to study because he or she has done or is doing something unique. Consequently, a parsimonious starting point is to assume that if the person does something unique it is because he or she is unique. Creative work is almost by definition difficult, and success improbable: Correspondingly, it requires vigor, boldness and persistence. *But these may come about in many ways*. A sick person may be vigorous in work by carefully husbanding energies. Darwin was bold in his study for many years, but circumspect in his relations with the world. Persistence can be expressed by unremitting toil, or by sporadic returns to a nagging problem.

To be sure, also, the creative person doing something very special may have developed some very special abilities. But we need not assume, without examination, that these abilities pre-existed and made the work possible. Applying the idea of "determination from above" (Wertheimer 1945)—now sometimes called "top-down processing"—to this relationship, it may well be that the person works to perfect certain skills because those skills are needed for his or her chosen tasks. Leonardo drew a thousand hands and *then* painted the *Last Supper* with its marvelous hands. The Nobel prize winning chemist, Robert Woodward, was noted for his seemingly miraculous ability to visualize chemical structures: He spent thousands of hours making structural drawings of molecules that his colleagues thought could be well enough represented by chemical equations. No wonder they later marveled at his aesthetic, intuitive feel for structure.

## THE PLACE OF UNIQUE PHENOMENA IN SCIENTIFIC THOUGHT

Of course, every human being is unique. Of the creative person it might be said that he or she becomes unique in more and more interesting ways by persevering at interesting work.

This state of affairs leaves us with a difficult problem. How will we make a science of the study of creative people, if each object in the domain, i.e., each creative person, is unique? Does science not necessarily aim at universals and general principles?

Yes and yes but. If each person in our collection is unique, we can still hope to arrive at some general principles that help us to understand each such unique configuration. For example, suppose it be the case that a person doing creative work must have some strategies or heuristics for identifying unusual ideas, recording them, and elaborating them. We might call this a *deviation amplifying system* (Maruyama 1963). There are probably thousands of ways of doing this, and an indefinitely large number of combinations of these. We could develop in ourselves a set of skills of studying such configurations without ever having to assume that any two are alike. This attitude is similar to the idea of the evolution of new species. We cannot predict which phenotypic variations will occur, only that they must obey certain constraints and satisfy certain functions; our hypotheses are not disappointed if yet another unique species is discovered.

Instead, our comparative anatomists, geneticists, etc. set to work to try to understand this new configuration in the living world.

You may ask, in wondering if we should devote all this energy to studying creative people: Suppose we go along with your next step, that this is not only interesting in its own right, but that understanding innovation is important for understanding the environments in which everyone lives. Can we take the next step and also say that learning about extraordinary people will help us to understand ordinary people? If we cannot generalize from one creative person to another, how in the world can we generalize from a collection of them to the person in the streets?

No, we cannot legitimately make inductive generalizations of this sort. But what we learn about creative people may teach us *where to look* to understand more ordinary lives. For example, the idea of *network of enterprise* became evident in the study of creative lives; it is readily extended to other lives; in my current research I am beginning to look into the origins of such networks in children. To take another example, the idea of an *ensemble of metaphors*—an interacting group, rather than a single ruling metaphor—became important in studying Darwin's life; it has now been readily applied to other creative lives; and it could readily be extended to more ordinary people. In fact, a cognitive anthropologist, Naomi Quinn, has been applying a similar approach to people's representations of the state of marriage (personal communication).

The *evolving systems approach* helps us to understand the frequent failures of proposed measures of ability both formal and informal. This problem was foreshadowed in Francis Galton's pioneering *Inquiries Into Human Faculty* (1883). Hardly any idea is more deeply rooted in the folklore of creativity than the belief that strong visual imagery is an important asset. Yet the majority of scientists in Gallon's famous "breakfast table" questionnaire claimed that visual imagery was unknown to them. Galton was astonished and concluded "They had a mental deficiency of which they were unaware."

For a while, from 1950-70 there burgeoned a psychometrics of creativity, and an arsenal of tests now exists. But the yield of validity studies has been close to zero. Getzels and Csikszentmihalyi's (1976) important book, *The Creative Vision*, reports a follow-up study of art students. It was indeed possible for the authors to tease out of their many observations some correlations between an early sample performance and later success in the art world. But results of quasi-standardized tests of creativity yielded little. Barron and Harrington (1981), in a recent review concluded that there was no evidence for the validity of existing tests of creativity. Except for the highly questionable practice of validating one test against another, few such validity efforts have been made, and those have failed.

I think the problem may reside in applying the whole logic of psychometrics to the issue of creative work. In order to measure an ability, the psychometrician must find some variable on which it is reasonable to test a fairly large population. If any validation studies are done at all, the prediction is made that some special population will score higher than the rest. But in the case of creative people, each one may become excellent at something no one else has even thought of or cared about. Yet, by the time a creative person has won his or her struggle to bring that "variable" to others' attention, it would no longer be a good measure of creativity. Today, for example, with powerful computer graphics techniques available, Robert Woodward's long nights of reconstructing molecules by painstaking drawings would not avail him much. Today's creative chemist must do something else that has not been dreamed of yet, and which therefore cannot be an item in the psychometrician's battery.

In other words, the *evolving systems approach* does not lead us to reject the idea that creative people have special abilities. I argue only that the attempt to freeze the profile of the creative person in a battery of tests displays a complete and disastrous lack of historical perspective. A good antidote to this ailment is *Born Under Saturn: The Character and Conduct of Artists, a Documented History from Antiquity to the French Revolution* (Wittkower and Wittkower 1963). In this penetrating survey by two distinguished art historians, the authors conclude that their evidence "militates most strongly against the existence of a timeless constitutional type of artist" (p. 293). Perkins (1981) makes a similar point.

A second and closely related difficulty in the psychometric approach to creativity is the loose attitude toward criterion levels. Studies of the gifted sometimes use a criterion level of the upper one percent of the population. This leads to moderate correlations showing that the gifted, so identified, lead quite successful lives, stay married, are healthy and well adjusted. Such claims may well be justified, but they have little or nothing to do with an adequate description of highly creative people.

We should not really be surprised at the failure of attempts to measure creativity. The creative person does something unique because he or she is unique, and is so in unexpected ways. Obsessed by her subject she comes to know more about it than anyone else and more important, to know it in a different way. Köhler has given a good account of the changes in the psychological field that come about as a result of such non-pathological, creative obsessions. Keller, in her recent biography of the great geneticist, Barbara McClintock, has shown how one life exhibits a quality of "strangeness"—not mere superiority in what others also do well, but excellence in something as yet unthought of—in McClintock case, *A Feeling for the Organism* which is the title of Keller's (1983) book. Keller's central point is that most geneticists had been interested in certain abstractions that they hoped to test and elaborate without much regard to the particular organism being studied. Unlike her seniors and contemporaries, McClintock immersed herself in the life of one organism and came to know corn genetics at a level of intimacy down to the individual, unheard of by her colleagues. Her strange approach made it possible for her to discover fundamental aspects of genetic patterning that had gone unnoticed.

## THE ORGANIZATION OF PURPOSE

In addition to these unique aspects of the organization of knowledge, the creative person works out a special, highly personal organization of purpose, expressed in his or her network of enterprise. Although this can take many forms, it may be that each part must operate in a context that both nourishes it and disequilibrates it, so that progress here creates a problem there, and the person is "never at rest," which is the title of Westfall's (1980a) biography of Newton.

Each creative person probably also constructs a unique organization of affect. But here psychologists know the least. Freud wrote somewhere that before the problem of the creative artist psychoanalysis must "lay down its arms" (See Jones, vol. 3, chapter 15, 1957). Psychologists have no powerful theory of those positive emotions that must play a powerful role in organizing creative work—such as joy in nature, passion for truth, outrage at injustice. Although Kurt Lewin and his group made a promising start in the study of "level of aspiration," little or nothing has been done to extend this concept to the study of creative lives. From my work thus far, nothing could be more obvious than that people like Darwin believe that they are doing something that has never been done before, that they want to do something new, and that they suffer knowingly the anxieties of life in the vanguard. Indeed, they must have some grasp of where they stand in relation to their fellows, for this knowledge is an important guide to creative work. Moreover, nothing is more powerful than the sense of personal identity, and my purposes are a part of my identity, not of yours! Darwin would have been dumbfounded and disturbed to wake up one morning and find that he had just taken a step that was a part of the network of enterprise of his contemporary, Faraday! The individual's activities must be mapped onto his own organization of purpose, and the constant renewal of this mapping forms an essential part of the creative person's identity.

## RECENT GROWTH IN INTEREST AND UNDERSTANDING OF SCIENTIFIC THOUGHT

Whatever we might mean by "upper" levels of development, it is bound to include scientific thought. We probably now know much more about scientific thinking than about other domains (a disparity that remains to be discussed). In several quarters, knowledge of scientific and quasi-scientific thought is being vigorously pursued: history and philosophy of science, genetic epistemology, psychology of science, and sociology of science are some of the disciplinary rubrics employed, along with Big Brother, cognitive science. The "psychology of science" enjoys an uneasy relation with the booming field of "cognitive science." Its subject matter is far too complex to satisfy the thirst for simplification and formalization exhibited by the latter. Yet the two exist side by side and give each other useful hints.

This very connection between cognitive science and the psychology of science brings out new gaps in our knowledge. As yet, there is no way of linking the clearly stated heuristics, algorithms, and production systems of artificial intelligence to the vague intuitions and strange cathexes that guide creative work. True, the *General Problem Solver* (Newell, Shaw and Simon, 1962) over twenty years ago could prove a theorem from *Principia Mathematica* but it took Bertrand Russell to conceive of the task of making that work, to invest it with his peculiar intensity, and to find the necessary collaborator (Whitehead and Russell, 1925-27).

There is nothing yet either in artificial intelligence or in more conventional cognitive psychology that can deal, for example, with Newton's lifelong preoccupation with alchemy. I am not advancing the by now tired argument that artificial intelligence will "never" simulate this or that cherished feature of human intelligence. One might as well say that psychology will "never" understand creative work. In this quest, both disciplines are simply tools.

Newton's life is instructive in other ways that pertain to our present discussion. For years, the comfortable belief was prevalent that as a young man he did all his properly cognitive work, enjoyed his "annus mirabilis," and after that simply filled in and perfected a scheme he had already grasped. Then, well past his prime, he took up arcane subjects. We now know this picture to be almost entirely false.

His miraculous year was really two years, age twenty-three till twenty-four. He did indeed sketch out a lifework for himself and produce many important insights. The multifaceted work of that period is an excellent example of the emergence of a network of enterprise—a set of lifetime tasks that guide the person's work over many decades. At the same time, as Westfall (1980b) has shown, he was very far from mastery of the problems he had set himself, or solutions. If we are willing to chop up creative work into parts, such as thinking of good questions and thinking of good answers, we may say that most of the job was already "done" by young Newton. But no serious historian of science any longer entertains that view. Newton, too, needed his lifetime of creative effort.

Even more troubling for the purist in cognitive science is the role of arcane subjects in Newton's life. We know now that these interests were *not* consequent upon a late middle-aged weakening of his intellectual powers but emerged very early and remained with him to the end. Although there was almost certainly some hoped-for connection between his more conventional scientific thought and his alchemical ideas, he also distinguished between them. He had some clear and effective sense of which part of his thinking formed a coherent whole that belonged in his *Principia*, and which parts to withhold from the world. This complicates the problem for psychologists who are interested in the whole person, in the integrated working of a number of parts or loosely coupled subsystems. Thinkers like Newton are often guided by broad points of view that do not fit easily into the currently available cognitive story. To add only one brief example, Niels Bohr, a giant of quantum physics, was struck by William James' idea of the stream of thought. He gave newcomers to his laboratory a Danish novel to read, an early example of stream-of-consciousness writing, in which the main character, going up the stairs meets himself coming down. Bohr thought that would help his collaborators to do good physics! (Gruber and Vonèche 1976).

The life of Newton brings out other important features of creative work—the role of self-criticism, level of aspiration, and social interaction. He has been painted as a lonely man, and indeed he was. Wordsworth's lines about him give the picture:

> Newton with his prism and silent face
> The marble index of a mind for ever
> Voyaging through strange seas of thought alone.[5]

But in some ways this is an exaggerated picture. Even Newton, that most secretive and private of men, knew how much his work would mean. And for all his secrecy, his work was connected to the world's work, and he had ways of letting the world know this, before he published *Principia*. How else account for the famous conversation between Robert Hooke, Christopher Wren, and Edmund Halley. They discussed the possibility of proving that gravitational attraction (an idea already having some currency) varied inversely with the square of the distance. As none of them saw a way of proving it, Halley went up to Cambridge to visit Newton. He asked Newton for the shape of the curve of planetary orbits if gravity varied inversely with the square of the distance. Newton answered immediately: an ellipse. He had already calculated it and could provide Halley with the proof—except that he had lost it in his study! Not long after, he sent Halley not one but two proofs. A strange man, but not out of contact with the world.

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5. Wordsworth William. The Prelude. Book III, lines 60-63.

In this essay, I have stressed the many areas of our ignorance about creative work, especially how to understand the process as a whole. But none of this is intended as a cry of despair. Even though we do not yet quite have our paradigm, we are making a sort of within-paradigm progress. We have a tolerable if very rough sketch of the *evolving systems approach* that must guide the study of creative work. We have won a certain degree of acceptance for the intensive study of the single case as a useful method in scientific research. This point should be qualified by the admission, or complaint, that it is still very hard to get financial support for this kind of research.

There remains a steady if relatively low interest in understanding the whole person as the necessary scene of creative work. It must be admitted, however, that "personology" is not a very popular sub-discipline of scientific psychology. On the empirical side, Carlson's (1970) complaint—"Where is the Person in Personality Research?"—could be written today. On the theoretical side, the idea of the creative person as an evolving system—loosely coupled organizations of knowledge, purpose and affect—represents a programme rather than an achievement. Actual theoretical models capable of accounting for the creative work of any single person are still far out of reach, and efforts in that direction—including my own—remain primitive.

Scientists and intellectuals working under many different banners do now form a loose federation, or "invisible college" interested in most of the questions I have raised here. Philosophy of science, history of science, genetic epistemology, dialectical psychology, cognitive psychology, cognitive science, psychology of science, psychohistory, creativity research, and personology—these rubrics describe not only the work itself, but also a search for kindred spirits.

These different fields often tunnel through to each other and find useful linkages and illuminating connections. As for whether we will ever really understand creative work, any possible answer to that question depends on the criteria of understanding. For the present, I want only to register one objection to the notion that understanding requires simulation. In the long run, we do not need or want to substitute machines for people. We want to understand ourselves well enough to make our lives better, or at least possible.

In other words, simulation is not necessary for the requisite understanding. At the same time, it may not be sufficient. Even in AI circles the realization is growing that we may be able to write programs that can accomplish certain tasks without our quite understanding how they work. Carried far enough this process will lead to a new science, the psychology of the computer. The computer-generated solution of the four-color problem in topology led to just such a dilemma. The program was too long and complex for its operations to be checked by humans. But the central idea of all mathematical proof is that every step must be open to inspection and found valid. Here instead, mathematicians had to have faith in the computer. Every simulation is really a man-machine interaction, in which it is not easy to decide who or what put which into what or whom. This point emerged as a central problem in a dissertation at

M.I.T. on the simulation of the composition of an animated film telling a version of the Cinderella story. "Who made the film?" remained the unanswered question (Kahn, 1979).

## THE IDEA OF PROGRESS, TIME PERSPECTIVE, AND THE FEELING OF PERSONAL AGENCY

Who made the film?

We might well ask a question more portentous for the future of all environments in which human development might take place. If the nuclear arms race and other species-destructive patterns continue their accelerated growth, our future looks very dim. The waging of war will become more and more automated. Then the question will arise in the minds of any that remain: Who or What made the war?

Developmentally, this future is now upon us. The world in which adolescents and young adults live is one in which the risk of species self-destruction looms large. When I grew up academically, we learned about feelings of helplessness and despair as part of psychopathology. Now it is reasonable to feel helpless and without a future. More than one reasonable position being possible, I do not go so far as to say it is unreasonable to feel hopeful and to be future-oriented. But at the present rate of events that day may come.

The objective bases for such questions and feelings are part of the everyday environment of every young person. Those young people who are consciously aware of this profound historical change in the developmental process can reasonably say "If I grow up ..." instead of "When I grow up ...."

The ecological system that forms the largely unspoken environmental premise for our developmental theories is one in which cultural stability is the rule, and familial stability, if not the rule is the norm. Much of education, especially in the United States, is built on the idea of upward social and educational mobility as a distinct possibility for everyone. The internalization of such societal models that permit growing up hopefully is an integral part of the production system of our societies, and is also inherent in our theories of development.

We do not only premise the idea of individual progress within our theories, we also assume that it is part of the growing person's own mental equipment. The child may say "When I grow up I want to be an astronaut." We expect all sorts of changes in the last word of that sentence. But we do not have a place in our theories for a normal developmental pattern in which its first word changes to "If ..."

Closely related to this sense of stability, futurity, and hope is the feeling of personal agency. The growing person needs to feel that some of what happens in the world is due to his own purposeful actions (Gruber, 1984b). According to Piaget and Inhelder (1969), even the experience of an objective causal texture of the environment begins as a projection of this feeling of personal agency. In the long run, for the young adult, this sense of effectiveness must reach beyond moment to moment activity and shape the emergence of longer term perspectives. We call this a *sense of purpose*.

To sum up this argument: (1) without a sense of personal agency there can be no meaningful idea of maturity; (2) intellectual growth takes place within a social-affective-historical framework that creates the possibilities for the feeling of personal agency; (3) threats to species survival provide the ultimate attack on this feeling of agency; (4) confronting these threats means taking personal responsibility to act toward their abatement. Without such confrontation the whole idea of personal maturity is called into question.

One of the major ideas behind this essay is that developmental theory must be responsive to historical change. Although this is not a new idea (see Fischer and Bullock, 1984), it needs more vigorous pursuit and more precise representation in theoretical work.

*Upoem* was written for my daughter when she was a small girl, I included it in the talk on which this chapter is based only to suggest that we developmentalists had not thought enough about the idea of progress. In the eighteen months since our Symposium, the nuclear arms race has continued and other threats to human survival have deepened. None of them have lessened. My daughter's son was born during our Symposium. As I write, he is now at the age when he can produce the one-word utterance, "Doggie," when he meets a squirrel or a horse. I want him to grow up in a world where, when he and his fellows meet their Russian counterparts, they will all feel, "There can be only one side—Humanity."

If developmental theory must be responsive to historical change, scientific criteria for cognitive-social developmental progress must from now on include the changes in patterns of human thought and in patterns of personal identity necessary to bring this utterance about.

# CHAPTER 6

# Coping with the Extraordinary

## *On the Relation between Giftedness and Creativity*

If you believe that giftedness and creativity are each a measurable quantity, you are in a good position to examine their correlation. A surprising number of psychologists do so believe, and this dictates the methods to be used. If, on the other hand, you are skeptical about the value of measuring the "amount" of someone's creativity, you need to search for other methods.

The group of papers in this section stem from this skepticism. Until 1983, it was nearly heresy to reject the belief that both giftedness and creativity exist in some amount (admittedly there were many skeptics). But Gardner's theory of *multiple intelligences* (1983) effectively challenged a fundamental assumption underlying the measurement approach by claiming there is not one intelligence but rather seven, later changed to eight. In my view, this does not go far enough, but it has opened the way to methods based on other premises. Even if it turns out that Gardner's eight is far too small a number of intelligences to account for the vast range of the human mind, the wide acceptance of this theory in education has led many classroom teachers to adjust methods of teaching to accommodate the diversity to be found in any classroom.

Still, this approach does not satisfy many developmentalists. Why only eight types? Even in such restricted populations as theoretical physicists there are gulfs between individuals that make communication between different "types" almost impossible. When Richard Feynman showed how to solve problems in quantum electrodynamics with a radically innovative method (using what is now known as "Feynman diagrams"), it took another brilliant physicist, Freeman Dyson, a year or so of devoted study to master Feynman's methods sufficiently to teach others working in what Gardner would have to call the same *domain*.

If even within a single taxonomic group like butterflies, there are between 10,000 and 20,000 known species, it seems too simple to frame the discussion around only eight types of human intelligence. "Community of descent is the hidden bond which naturalists have been seeking, not … the mere putting together and separating objects more or less alike" (Darwin 1859, 420).

Creators struggle against the limits of their abilities, as well as against the limits of knowledge as defined by their worlds. To accomplish truly creative work means to persevere in that struggle beyond the ordinary, beyond whatever has been known, discovered and, maybe, even measured. To borrow a notion from Vygotsky, the creator forges his own *zone of proximal development*—in essence, creating his own gifts. He is not a passive vessel filled with "gifts."

Instances of extraordinary creative accomplishment examined through the lens of the *evolving systems approach* teach us a much broader idea of human capacity than the study of a few, fixed extraordinary "intelligences." Our investigations were meant to uncover not how much creativity someone has, but how it works. Specific systems are organized to work in different ways. For example, in a negative feedback system, deviations from the norm are reduced or eliminated thus maintaining the integrity of the system. In a positive feedback system, deviations from the norm are amplified. To deepen our understanding of highly creative behavior, it is important to reflect on the organization of the system in question. It may well be that the difference between an ordinary person and an unusual one is not determined by inborn factors but by relatively small variations in this organization. Heroes—people whose behavior surpasses normal expectations—may be working with such *deviation amplifying systems* (Maruyama 1963). Most systems must be negative feedback systems, or the world would be unstable, even more chaotic than the one we know and live in. In short, instead of explaining the unusual, or gifted, by appealing to fixed traits, we look for systemic factors which magnify the unusual and make it more *visible*. Can this same line of thought explain the very unusual, the extraordinary? I think so. Perhaps it is necessary to join a number of subsystems that mutually drive each other in optimum ways. But such synthesis does not just happen. It requires the courage, the commitment and the vision of a creative person, hard at work.

# On the Hypothesized Relation Between Giftedness and Creativity

There have been three main ways of studying human extraordinariness separated by high walls. Some investigators study *giftedness*—children functioning at unusually high levels; giftedness is often equated with precocity. Others study adult creativity—either the personality of the creative adult or the process of adult creativity—focusing on indisputably outstanding individuals. A third group study supposed creative processes in ordinary individuals; these are usually experimental or quasi-experimental studies.

In this essay I undertake three tasks, all guided by the ultimate hope of someday breaking down those walls. My first task is to examine the reasons one might have for wanting to understand extraordinariness and its development. Here, I hope also to show that there are important relationships among the guiding reasons, the research methods adopted, and the problems encountered. My second task is to examine three quite different ways of framing the idea of giftedness: the person as given, the child as child, and the person as developing. Again, the choice of frame controls the research strategy that emerges. A third task is to sketch the evolving systems approach to the study of creativity that my students and I have been working on for some years. This approach serves as a framework for my insistence that we reexamine the connection between giftedness and creativity. I will argue that we know only a few adult cases reasonably well and almost nothing about the childhood origins of the most important aspects of these adults' creative work. By the same token, then, there must be a large gap in our understanding of the growth of creativity from childhood on.

## Why Study Extraordinary People?

## Why Study Extraordinary Qualities in People?

I put the question in these somewhat different ways in order to avoid prejudicing the case regarding a difficult question. Some would have it that every child is gifted and the central goal should be to discover each child's gifts and nurture them. This position is put forward in a novel way in Michael Armstrong's *Closely Observed Children* (1980). Others would have it that only some individuals have extraordinary gifts and the central goal should be to discover and nurture those few; this is the prevailing view in the gifted child movement.

For the time being, we do not need to choose between these two formulations. Indeed, making a premature choice might narrow our vision and lead to neglect of important issues. For example, if indeed every child is gifted in some way or other, to

Shortened version of Gruber, Howard E. 1982c. On the Hypothesized Relation between Giftedness and Creativity. In *New Directions for Child Development: Developmental Approaches to Giftedness and Creativity*, edited by D. Feldman, 7-29. San Francisco, CA: Jossey-Bass.

accommodate everyone there must be a large variety of gifts—that is, ways of being extraordinary. Such a conception would dictate a particular search strategy (wide search pattern, prolonged observation) in looking for the gifts that are our objects of study. If, on the other hand, our definition of giftedness is much narrower and the variety of gifts smaller, the search strategy now popular (small test battery reduced to a very small number of scores, infrequent tests) might be appropriate.

Our committee, as evidenced in its name (the *Social Science Research Council Committee on Development, Giftedness, and the Learning Process*), is committed to the study of the development of extraordinariness. We believe there is now enough evidence to argue confidently that extraordinary talents require long growth and much nurturing. Since this growth process is poorly understood and for the most part ignored, one of our tasks is to foster the study of extraordinary development.

We also believe that early gifts, no matter how they are evidenced, do not necessarily flower into creative achievement or creative lives. Again, the connection between giftedness and creativity is poorly understood. From a research point of view, looking only at giftedness without looking also at the adult creative process might well lead down a blind alley. A widely successful heuristic in problem solving is to reason backwards, from the characteristics of the desired solution, to the penultimate steps leading to that end state, to the steps before those penultimate steps, and so on back to some known or attainable starting point (Newell, Shaw, and Simon 1962; Polya 1957). If we apply this heuristic to our present tasks, it means that we must look at the mature creative process and ask what the steps are that lead up to it. (I use *creative* here in a large enough sense to accommodate all sorts of effective extraordinariness).

Given that our chief goal is to understand extraordinary development, we need to link up the study of giftedness with the study of creativity and to study the growth of this connection in the individual.

Let us return to our starting point, and rephrase it a little. We study the development of extraordinariness because we want to know what people are like, not only in the ordinary vale of tears, a humdrum mixture of misery, fear, and small pleasures, but what they could be like, *what life could be like*. Most psychology and social science addresses itself to the typical. But our understanding of the human condition should transcend momentary reality and include a grasp of the possible. Malaria is endemic in some parts of the world. It is typical, but not normal, not optimal. In a malarial world someone must construct a vision of unheard of health. In a world of anomie and mediocre education, someone must construct a vision of people at their best. Looking at extraordinary functioning where it does occur is one way to construct that vision.

*To understand all human beings*. If we couple a hard look at the optimum with a careful examination of the differences between it and the typical, we may hope to understand the latter as well as the former. Of course, we do not mean to look only at attributes but also at conditions of life and development. This kind of scrutiny can be pursued by closely comparing the optimal with the typical. It is well illustrated in

Joanna Field's *A Life of One's Own* (1952). She noticed that sometimes she was happy and other times not. She kept a diary to help her understand the difference between these two phases of her life and rediscovered a gift for experience that, as a striving professional, she had lost.

*To facilitate innovation, to foster the transformation of human existence.* Few will deny the existence of seemingly intractable social and human problems. I forbear to list them here. Few will deny the need for extraordinary talents, both to invent and to implement solutions. Not least among the problems is the thwarting of human development, so that nurturing extraordinariness is both an end in itself and a means to other ends. But to nurture one must understand.

*To improve the chances of human survival.* Again, few will deny that human beings now constitute a major threat to their own environment or that the danger of thermonuclear war poses a threat to our existence as a species. Even now there are recognized fields of endeavor that draw upon gifts relevant to these problems—the gifts of sympathy, morality, cooperativeness, altruism, commitment, love of life. If we need to think in new ways, we need to search for and focus on gifts that will lead us in new directions.

Here is an episode (as retold in the epic poem *Peace March*; Brand 1980, 34) from the life of one child, Sadako Sasaki, that underlines the reason for the search:

> *The crane*
> according to Japanese legend
> lives a thousand years, so a paper crane means a wish
> for a happy, long life.
> Ten years after the atom bombing
> a twelve-year-old girl in Hiroshima,
> Sadako Sasaki, who had been exposed
> to the bomb's radiation,
> developed leukemia. A friend
> sent her a letter in the hospital,
> enclosing a paper crane.
> Sadako thought,
> If I fold a thousand cranes,
> I have to get well.
> She folded
> nine hundred and sixty-four and died.

Now, in Hiroshima's Peace Park there is a bronze statue of Sadako, holding over her head a crane in bronze. The paper crane has become the symbol of the Japanese peace movement.

Was Sadako Sasaki gifted? Who sculpted the crane? Who made the symbol? Was she creative?

## CONCEPTUAL FRAMEWORKS FOR THE IDEA OF GIFTEDNESS

The term gifted has come to represent an implicit hypothesis about the adult performance of a person identified as extraordinary in childhood. The hypothesis has three parts: (1) the preformationist belief that, at some point early in life, the "die is cast," the person's potential is defined and circumstances merely dictate the degree to which the potential will be achieved, (2) the prediction that extraordinary children will become extraordinary adults, and (3) the more detailed prediction that the domain in which the child is extraordinary is a good indicator of the domain in which he or she will be extraordinary as an adult. The point chosen for fixation of the future varies. For some members of this family of approaches the die is cast at the moment of conception, for others in infancy or in early childhood, and for still others some time in adolescence. All these, taken together, may be contrasted with views that postulate a person permanently engaged in a process of self-reconstruction.

In practice, this preformationist belief system has been closely allied with psychometric approaches to measuring abilities. This alliance has often led to the identification of giftedness with the supposedly best measured ability, IQ. This set of ideas has had the unfortunate consequence that many psychologists have turned away from the study of extraordinariness because they do not like or trust the peculiar products of this by now conventional marriage of preformationist and psychometric thought.

But *Homo sapiens* is an extraordinary species, and our most creative and interesting members, rather than the typical, may best represent our essential nature. Human extraordinariness is too important to be left under the sole guardianship of preformationists and psychometricians. Let us now consider three of the possible frameworks for the idea of giftedness.

### *Person as Given*

In spite of the very thin evidence, there is an almost overwhelming tendency to believe that the individual maintains a constant position in a series of three parallel "scoring systems." The form of the accepted argument runs: The child's score on X is a good predictor of the adult's score on Y. In this preformationist perspective, the ideal case would look like child A or child B in Table 1.

No one would be interested in the correlation $r_{XcYa}$, unless he or she also believed that this measure had implications for $r_{XaYa}$ or, through a natural short cut, $r_{XcYa}$.

It is generally taken for granted that $X_c$ and $X_a$ are scores on similar tests, or tests of the same ability, simply adjusted for age. The major tests in question are constructed to produce monotonic functions in which performance improves steadily (up to some limit) as age increases. Precocity and percentile standing in comparison with one's agemates have the same measure. From this it follows that precocity in $X_c$ is regarded as the best predictor of $Y_a$.

*Table 1.* Four developmental pathways

| *Test X* | | | *Test Y* |
|---|---|---|---|
| *Individual* | $X_c$*(Child)* | $X_a$*(Adult)* | $Y_a$*(Adult)* |
| A | high | high | high |
| B | average | average | average |
| C | high | high | average |
| D | average | average | high |

Let us for the moment accept the widespread view that originality and creativity are almost the same thing, so much so that divergent thinking tests of originality are deemed good indicators of creativity. Let us combine this assumption with another, the idea that precocity in cognitive variables of the kind measured in Piagetian tasks are, as ought to be expected, well correlated with general intelligence as measured by IQ scores. Remember that Piaget deliberately chose tasks revealing universals of intellectual growth. Then, aren't we saying that rapid progress along this well-trodden path—that is, precocious achievement of widely shared ways of thinking and acting—is a good indicator of future performance in tasks requiring originality of conduct in situations requiring departure from the generally accepted? To make the point as clear as I can, I will recast it as a series of propositions.

*Argument 1.*

Proposition 1. Precocity means rapid progress in conventionally recognized, valued, and widely achieved cognitive skills.

Proposition 2. Rapid progress in developing these conventional skills leads to later success in creative work.

Proposition 3. Childhood precocity can be used to predict adult creativity.

*Argument 2.*

Proposition 4. Creativity entails doing something new.

Proposition 5. Originality is essential to creativity.

Proposition 6. Measures of originality are predictive of creative achievement.

Argument 1 and Argument 2 combine to produce

Proposition 7. Precocity in conventional cognitive skills can be used to predict adult creative achievement.

Why not expect just the opposite of propositions 3 and 7? The child who hangs back in going down the universal path may be just the one who keeps his or her eye fresh for new views of the world. Then the relevant picture might look like child D in Table 1. But this is an odd way of looking at matters. Is there any evidence that gives it some credibility? Yes:

Artists must be able to suppress or avoid the normal perceptual constancies. For the ordinary business of living we must see the far off man as six-feet tall, the saucer on the table as circular, the piece of coal in the sunlight as black. The artist, however, must be able to see far off objects as smaller, the saucer as oval, and the coal in the sun as bright, for that is how they must be painted to give a realistic impression (Gibson 1966; Gombrich 1960). Nor is there any correlation between these normal perceptions and those of artists (Gruber and Clark 1952).

Getzels and Csikszentmihalyi (1976) found a negative correlation between divergent-thinking scores of art students and their creative success in the art world some five years later.

Numerous investigators have failed to find a large correlation between measures of intelligence.

Albert Einstein as an adult obviously had a very special way of looking at the world; as a child, far from being precocious, he was slow to speak and unsuccessful in school.

I grant freely this is not an ironclad case; other evidence could be cited supporting the conventional picture of the relation between early giftedness and later creativity. But not very much. I wish only to propose that unconventional views, such as those just discussed, are not entirely implausible. It should, moreover, be recalled that Piaget, on grounds different from those I have cited, mounted a powerful attack on the preformationist point of view entailed in the acceptance of the child as given.

### *Child as Child*

There is an almost overwhelming tendency to discuss giftedness in relation to the future of the child rather than the present: Who will she become? Will he succeed? Will she be truly great?

But it is possible to imagine a different perspective. The gifted child might be the one who, as a child, most enjoys himself or the one who most entertains us. Or she might be the one who is most helpful now. Or the one who can make the most wonderful art now, even though we know, from Gardner's work, that this gift will almost inevitably fade (Gardner 1980a).

Most of us do not get much pleasure out of contemplating measurements for their own sake, but someone who did might call that child gifted who now displays an enjoyable measure of height or a pleasing intelligence test score.

There are, then, experiential, utilitarian, and aesthetic perspectives that might orient us without our stepping out of the present. But no, we are all thoroughly committed to those meanings of giftedness that have implications for the future, for the adult to come.

The most striking exception to this tendency that I know of is Michael Armstrong's work (Armstrong 1978, 1980). Watching each child in a school over many months, he sees one as a philosopher, one as a poet, one as an artist—each seriously engaged in a special pursuit, often quite unobtrusively. Since each is special, only a few would be caught in the net of a testing procedure fishing for giftedness on a few standard dimensions. (Armstrong makes no claim about the future performance of these children. He tells us only that if we want to see how each child is special, we must watch patiently and closely.

I do not know how to deal with this thesis in the present context. My own research commitment has been to the study of adult creativity in unique cases; our shared theoretical equipment focuses mainly on cognitive universals. The specialness of a child seems to fall through our net. And yet, when we speak of adult creativity, the phrase "a sense of specialness" will not be strange to us. For the present I can only leave it as a question, but one to remember:

How do we deal with this quality we prize, specialness?

### *Person as Developing through Continuous Interaction of Organism and Environment*

At a sufficient level of abstraction, everyone claims to be an *interactionist*, agreeing that nature and nurture both contribute to development. But certain genetic factors seem so visible that, in practice, a theoretical interactionism often turns into a quasi-hereditarian point of view. It is asserted, for example, that hereditary differences account for most of the variance in some psychological variables, usually IQ. This position has come in for its share of criticism (to which I have contributed). But when we look at extraordinary children, their performance often seems so magical that the appreciative observer may relapse into quasi-hereditarianism. From a developmental perspective, this is most unfortunate: The observer is deprived of the keen vision needed to see the environment at work and deprived also of the lively imagination necessary to guide reconstruction of the environment in favorable ways. It is perhaps only a minor irony that, as far as psychology goes, the genes influencing intelligence and creativity are completely unidentified. Evidence for them is entirely circumstantial and statistical. In contrast, we can practically see the environment at work: On one side, the dark Satanic mills, on the other, the master working with her apprentice, the father playing with his baby.

This issue is so important to a developmental perspective on any human attribute that it is worth dwelling on here.

Everyone knows that the genetic make-up transmitted from generation to generation has a profound effect on development. No environmental manipulation will turn an infant chimpanzee into a human being nor a fox into a lynx. These are hard facts of biological science. Compared to these, claims of environmental effects on the course of development seem pale psychological speculations or wishful thinking. But let us look at some clear cases.

*A queen bee and a worker bee are genetically indistinguishable*. But they are profoundly different in form and in their function in the hive. The queen is longer and more slender, does little but mate and lay eggs. As a grub she and she alone eats the "royal jelly" provided for her by the worker bees. And it is this special feeding that makes all the difference between the one queen in the hive and her sisters, numbering thousands of workers.

Or to take an even more dramatic example, in the marine worm, *Bonellia viridis*, any young individual reared from an isolated egg becomes a female. But "if newly hatched worms were released in water containing females ... some of the young worms were attracted to the females and became attached to the female proboscis. These were transformed into the males and eventually migrated to the female reproductive tract where they became parasitic" (Gardner 1972, 143-144; see also Dobzhansky 1955). Thus, this environmental difference turned the course of development so that one individual became a large female, the other a tiny male living inside the female.

The dramatic effects of environment on development are found everywhere in the living world. They are hard biological facts, just as our knowledge of genetic transmission is, and indeed, they are as much a part of the science of genetics. There are different ways of understanding the interaction of heredity and environment; although we cannot go further into that complex subject here, it should be said that any simple solution is sure to be simple-minded.

On the side of mental retardation, there seem to be some clear and known cases of specifiable genetic mechanisms controlling the development of intelligence. One of the best known is phenylketonuria (PKU), a metabolic deficiency leading to severe idiocy and early death. But the genetic defect producing PKU is now known to be not a "gene for stupidity" but an inability of the child to avoid poisoning himself or herself with his or her own metabolites. When dietary compensations for the metabolic defect are made, the child develops normally. Something similar can be said for a number of other known conditions.

When we turn back to the topic of giftedness and creativity, we find absolutely no hard knowledge that imposes on us the intellectual necessity of believing either that the gifted are extraordinary because of superior genetic endowment, or that they are extraordinary because of some unusual treatment bestowed on them, such as that received by the queen bee. Insisting on one or the other conclusion or on some vague compromise is useless and confusing. We need to find another road for our thinking.

## TWO RESEARCH STRATEGIES FOR RELATING GIFTEDNESS AND CREATIVITY

### *Tracking the Process of Development*

In the long run, we would like to know exactly how every human being develops potential through his or her own thought and action in the world. We would like to be able to trace the steps of development and to understand the choices making up a particular developmental pathway and thus characterizing any person's life. We would like to know how very specific environmental events affect the course of development. Like embryologists, then, we would like to know how some people synthesize themselves in a long series of steps, through their activity in an everchanging environment. Then would we know:

| | |
|---|---|
| how a gifted child | becomes a creative adult? |
| how a gifted child | becomes an ordinary mortal? |
| how an ungifted child | becomes a creative adult? |
| how an ungifted child | becomes an ordinary mortal? |

It pains me to write the words *ungifted child*. Polite convention usually leaves this part of our professional jargon implicit, a case of silent euphony. Maybe it is worth the pain in exchange for the pleasure of making visible the sequence "an ungifted child becomes a creative adult." Piaget tells us that those who have achieved the stage of formal operations complete their tables of possibilities, and so should we.

We are very far from the advanced state of knowledge necessary to understand developmental pathways. We have a long row to hoe. Rather than starting at the beginning, we might apply the honorable heuristic of starting at the desired end state and working our way backward to whatever initial conditions existed.

### *Starting with Known Creators*

If we want to know how people become extraordinary adults, we can start with some of the latter, find out how they do whatever it is that we find extraordinary about them, and then try to find out how they came to do it. If we could understand the transformation of an adolescent into a creative adult we might then pursue the understanding of a child becoming an adolescent on the road to creativity. If we could understand an adult who has led a creative life, we might then work backwards to ask how this promising young adult organized his or her life as a whole so as to remain a self-actualizing, creative person.

At this stage of our work, we are not yet ready to trace the whole course of creative lives. But we can say a great deal about creative work, within a developmental framework.

## SOME PROBLEMS IN THE STUDY OF THE DEVELOPMENT OF GIFTEDNESS AND CREATIVITY

The problems facing us in the future study of the development of giftedness and creativity may be grouped under seven major headings, each a whole research domain.

The first problem is our incomplete knowledge of development. Our knowledge is incomplete in at least three fundamental ways.

### *Stages of the Life Cycle*

We are only beginning to look at intellectual growth in late adolescence and early adulthood. In early April 1981, there was for the first time a national symposium on investigators of postformal operations (Commons 1981). This grew out of the recognition that the attainment of formal operations, described by Inhelder and Piaget (1955) as being achieved in early adolescence, is by no means sufficient for describing high level adult thinking and creativity. Thus, in spite of the enormous upsurge of developmental research in the last twenty-five years, we do not have a complete picture of normal development. By the same token, we are ignorant of supernormal or extraordinary developments beyond early adolescence. In other words, at just that point in the life cycle where whatever we might mean by early giftedness must be transformed into effective extraordinariness, our knowledge runs out. Something similar could be said for all the later stages of creative lives (Gruber and Vonèche, 1976).

### *Unilinear Theories of Development*

Virtually all theories of development (Piaget, Erikson, Freud) are unilinear (Gruber and Vonèche 1977). In other words, each describes a single developmental pathway, a set of stages in which A prepares the way for B prepares the way for C and so forth. But if we are interested in unique or unusual gifts, how do we know that these fit neatly into schemata provided by unilinear theories? Embryological theories deal with differentiating structures; evolutionary theories deal with the branching system of nature. In just this area of giftedness and creativity, where we are concerned with innovation, differentiation, and the remarkable, how can we base our understanding on a unilinear theory of the repetitive, predictable, and unremarkable?

### *Focus of Research Limited to Universals*

One of Piaget's great achievements was to help psychology free itself from the trivial and the nonsensical by studying the intellectual development of profound and essential universals that had formerly been the province of philosophers: the child's ideas of object, space, time, causality, number, chance, and motion. This concern for universals properly characterizes almost all research on intellectual development. But if we are interested in the extraordinary, this knowledge must be linked up with new knowledge about the development of that which is not universal, that which is remarkable, unique (Feldman 1980).

The topic of conservation provides an example. We know that babies during the first eighteen months develop and perfect their idea of the permanent object. In the period of concrete operations children, untaught, develop the ability to handle increasingly complex aspects of the conservation of matter under the transformation of shape (Piaget and Inhelder 1966; Piaget 1952a). The adolescent or young adult will later be taught to use particular conservation principles to solve standard science problems. I have observed that, beyond that point, professional scientists often use the abstract idea of conservation principles to restructure a problem. Faced with the task of inventing an explanation for a known phenomenon, the physicist asks himself or herself, "What quantity is conserved in this situation?" and searches a repertoire of natural invariants for an appropriate approach to the problem. Beyond this, a creative achievement occurs when the scientist uses a similar strategy to guide the process of discovery. William Harvey (1963), for example, measured the rate of flow of blood past a central point in the circulatory system, found that the total amount passing the point per hour far outweighed the total weight of the body. From this he reasoned that the body could not be producing so much blood every hour; consequently there must be a return route, and the blood must circulate in a closed loop.

Thus he used an idea about the conservation of weight to guide a physiological inquiry. But we have no reason at all to believe that precocity in attaining conservation was important in such a life as Harvey's. Keeping alive the capacity to wonder, to ask strange questions about ordinary things when other children have settled matters and laid them to rest—this may well be the way to creativity. We need to understand the emergence of uniqueness and the relation between the unique and the universal. It may be the case, but we do not actually know it, that precocity in the attainment of these universals presages a life of creative achievement. But it is not unreasonable to ask, whether children who resist movement along the universal pathways—that is, are not precocious—include some who are most likely to see the world in a new way, or do or say something extraordinary. We do not know that precocity in universals portends extraordinariness in nonuniversals.

In other words, as we modify or reject psychometric traditions by introducing recent developmental thought, we should not make the mistake of confusing the typical with the optimal or precocity with originality.

The second problem is our *embryonic knowledge of creativity*. This is a vast subject and I will restrict myself to two points.

*Failure of Psychometric Approach.*

There was, for about two decades, an enormous investment of research energy into tests of divergent thinking. There is hardly a shred of evidence that scores on such tests correlate with real creative performance in any line of human endeavor (Barron and Harrington 1981). Indeed, there are very few validation studies that actually correlate test performance with real creative achievement (Fox 1981). One recent study (Getzels and Csikszentmihalyi 1976) found a negative correlation between divergent thinking scores and later success as an artist.

*Paucity of Case Studies*

There are very few case studies of the way creative people actually do their work. Charles Darwin is probably the best studied scientist, but even his work and life are very incompletely examined in spite of a wealth of available documentation (Gruber, 1981e). In particular, the period of his life representing the transition from adolescence to young adulthood has hardly been written about at all (Gruber 1984b; Vidal 1984). Perhaps Newton and Freud have been studied almost as much as Darwin, but after that the thread of knowledge soon runs out. We have a great deal of piecemeal, sketchy knowledge about creative people. Even excellent intellectual biographies are simply not detailed or searching enough to give us a picture of the creative person at work. It should be said that there is now a small but strong undercurrent of interest in doing this kind of research.

The third problem is to correct our ideas of giftedness and creativity with *studies of prolonged training*. In the area of training of prodigies, Feldman (1980) has made a good beginning. With regard to specialized training of the kind studied by experimental psychologists interested in attention, memory, formal operations, there is a small but important group of studies by Ericsson et al. (1980), Kuhn and Ho (1980), Spelke, Hirst, and Neisser (1976), and others. When the goal of an experiment is optimization rather than measurement of the typical, remarkable things can happen. In Ericsson' s study, for example, an ordinary college student reached the level of performance of a mnemonics expert (memory wizard) after only 200 hours of training. If something similar could be done with the same person for two or three cognitive skills and then for their intercombinations, we have no idea what might result.

The fourth problem is that *psychometric studies of giftedness have traditionally centered on IQ scores*. What little we know suggests that there may be no strong relation between very high IQ and creative achievement (see, for example, Getzels and Jackson 1962). Yet the major study of giftedness, Terman's, is centered around the concept of IQ. We have no tests that can discriminate between the Titans and their team members and no tests that can predict creative lives from early high scores (sometimes called giftedness).

The fifth problem is the *tuning problem*. When is a gift a gift? We slip easily into thinking that high achievement in science or the arts is what we need, what we mean by creativity. But is this the case? Today's gifted children must solve tomorrow's problems. American society has learned how to produce large numbers, probably large enough for social needs, of scientists and engineers. We, and our counterparts in other advanced nations, know how to create technological innovation. We are smart, but are we wise? If what is needed for the future are wise and compassionate people who will know what to do to preserve our species and make a better life, then shouldn't we search for ways of identifying and nurturing the gifts of wisdom and compassion? The psychometric and the Piagetian traditions share a one-sided emphasis on quasi-scientific intellectual attainments. Feldman (1980) has advanced the idea that creativity occurs when gifts are tuned to promising tasks. (Isaac Newton in the stone age would not have been gifted, nor the conductor Toscanini in a completely individualistic society.) From a practical point of view we are oriented toward the present and the future; but our research must be based on the present and the past. A thoroughgoing approach to the development of giftedness and creativity must deal with these questions of the interaction of person and world, of the place of the person in history.

The sixth problem is *the intimacy problem*. What shall be the standards for governing our search for the extraordinary? Suppose we have a list of seven good things: A person is gifted if he or she has a lot of GT's 1-7. Along comes someone with not too much of GT's 1-7 but a fantastic amount of 8. If we are only watching out for GT's 1-7, we may never notice this outlier. But the remedy does not rest with adding 8 to our list. The observer must be a person of great breadth who will notice something extraordinary whether it be 8 or 888. And breadth is not enough: The observer must be watching when the extraordinary thing happens. The psychometric ethos and the overcrowded classroom both militate against such patient observation.

The seventh problem is *the criterion problem*, studies of giftedness and creativity, which vary enormously in the level of attainment deemed unusual enough to be included in the study. Terman worked with the upper ten percent; Lehman's study of *Age and Achievement* (1953) is based on the all-time greats. Suppose Terman and others working in that vein had actually succeeded in predicting high achievement at the one-in-a-hundred level. What would that have told us about the one-in-a-million?

If we choose the path of raising our criterion level so that our primary interest is in very high levels of creativity (one in a million would mean a panel of 200 subjects in the United States today, certainly not all to be counted among the all-time greats), then something has to happen to our research goals. For rare events, known only after the fact, we cannot aim at finding methods of prediction and nurturance.

But we could find greatly gifted people, as evidenced by their work and lives, and study them closely. My point here is not to argue for one method of research. I wish to bring out the fact that there is a strong connection between our approach to the criterion problem and our choice of methods.

Imagine an astronomer who refuses to look at novas and supernovas because they are atypical phenomena. Or, on the other hand, imagine an astronomer who looks long and lovingly at these brilliant events in the heavens, goes to great pains to develop a special *astrophotometer* for measuring their departure from normal brightness of stars and concludes admiringly that, indeed, these stars are endowed with novoid genius. Still again, imagine a third astronomer who thinks novas are wonderful and, wanting to see more of them, recalibrates his or her instruments (to a lower criterion level) so that more bright stars will appear to them as novas.

But none of these savants would be using the brilliant phenomena of their domain for the main purpose that scientists have evolved in every field of successful inquiry —the long, patient struggle to make sense of the domain as a whole, to understand it.

To this end, unusual events may be particularly useful if they can be conceived of as magnifying or extremizing interesting processes and thereby making them easier to study. This would be the case with genetics, for decades using the fruitfly, *drosophila melanogaster*, as an experimental animal because it breeds rapidly and because it has unusual, giant chromosomes in the salivary glands that make it possible to observe quite directly various chromosomal configurations. This would also be the case with students of intellectual growth choosing children to study because processes of development are so rapid in the early years.

In another vein, unusual events may be particularly interesting if they can tell us about the origins of important phenomena. Evolutionists must be interested in mutations. But not for their own sake; this is the key point. The indispensable task is to link up these extraordinary events with the domain of inquiry as a whole, to use the novas to illuminate the heavens of inquiry.

## CONCLUSION

If we understood how a given system came to be we would have explained, for that person, the development of early gifts into later creativity. At present, we can describe reasonably well the development of a creative person from adolescence onward. But the early shaping of a creative life remains largely terra incognita. We know next to nothing about *networks of enterprise* in childhood and adolescence. The knowledge and belief systems of creative adolescence are given short shrift as "juvenilia," and consequently we have almost no picture of the evolution of the system of knowledge and belief between childhood and adulthood.

If we look more closely at the interweaving of cognition, affect, and purpose in creative lives we may in time learn something of how early gifts evolve into later creativity. Albert Einstein represents a marvellous lifetime organization of the gifts of intelligence, passion, and compassion—whose interdependence has been an arrière pensée throughout this essay. Einstein said of himself: "I have no special gift—I am only passionately curious. Thus it is not a question of heredity" (Hoffman and Dukas 1972, 7).

In this he was probably right. Hoffman, one of his biographers, himself a theoretical physicist and colleague of Einstein's wrote, "But talent is no great rarity, and by professional standards Einstein's scientific talent and technical skill were not spectacular. They were surpassed by those of many a competent practitioner" (Hoffman and Dukas 1972, 7).

Of curiosity and its fate, Einstein wrote: "It is, in fact, nothing short of a miracle that modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry; for this delicate little plant, aside from stimulation, stands mainly in need of freedom; without this it goes to wreck and ruin without fail. It is a very grave mistake to think that the enjoyment of seeing and searching can be promoted by means of coercion and a sense of duty" (Einstein 1949, 17).

But there is more to a man like Einstein than talent and curiosity. The same concern for unifying principles, underlying his thinking about the physical universe, dominated his social thought. He was a lifelong pacifist, and he saw this position as intimately connected with the nature of scientific thought. He wrote: "[Scientists] are inclined, by the universal character of the subject dealt with and by the necessity of internationally organized cooperation, towards an international mentality predisposing them to favor pacifist objectives" (Frank 1948, 191).

If gifts must be tuned to the historical needs of their owners in order to flower into creative achievement, then it is clear that in the next few decades mere intelligence will not be enough. To survive, *Homo sapiens*, the intelligent ape, must now evolve into a creature of deeper humanity and wisdom, *Homo pacificus*. Do we know how to find and nourish that gift?

# The Self-Construction of the Extraordinary

## Different Kinds of Gifts

There are gifts and there are gifts. The concept of gift is complex and ambiguous. There are the gifts of Lady Bountiful and Lady Luck, neither of which reflect much credit on the recipient. And there are white elephants and Trojan horses, neither of which do the recipient much good. H. G. Wells was often preoccupied with the deceptive gifts, ones that are of no use because they cannot be properly inserted into the social fabric: In *The Country of the Blind* (1911), the sighted person who wanders into that strange land finds he cannot dominate the inhabitants because they have found a coherent set of adaptations to their blindness; Wells's *Invisible Man* (1897) aspires to use his extraordinary power of disappearing by turning to a career of crime, but he fails because he comes up against a tough and resilient organization—the world as it is.

The kind of gift that interests me is the kind that can be transformed by its possessor into effective creative work for the aesthetic enrichment of human experience, for the improvement of our understanding of the world, or for the betterment of the human condition and of our prospects for survival as a species. In previous essays I have examined with some skepticism the hypothesis of a relationship of necessity and/or sufficiency between early giftedness and adult creativity.

In the present paper I hope to continue that examination. I hope also to give some account of this process of creative work, and to make some suggestions about how we might begin to think of its origins in childhood and adolescence.

The main body of my argument is carried by four points. First, the concept of "gift" depends for its meaning on establishing some connection between the property labeled "gift" and the development of an extraordinary adult. Because this connection has been quite difficult to establish empirically, an important research strategy is to identify extraordinary human beings and work backward to the processes and conditions that gave rise to them. Second, the main force in the development of an extraordinary person is that individual's own activity and interests. Third, the meaning and value of any particular kind of extraordinariness depends on the historical and social circumstances in which it appears. Fourth, our best hope for understanding the development of human extraordinariness is to study closely the lives of creative people. This entails radical changes in empirical methods, especially a greatly increased emphasis on the case-study method.

Altogether, I object to the aprioristic, all too easy assumption that gifts preexist and are somewhere out there remaining only to be given to their recipients. Rather, I believe that the qualities of human extraordinariness are striven for and constructed. Usually I avoid the word *gift* and prefer to speak of *human extraordinariness*. But this is sometimes a clumsy phrase. Moreover, since I grant that a common interest unites

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the authors of this volume and other discussions of giftedness—an interest in what human beings are like when they are at their best—I will sometimes concede a point and say giftedness for short.

Naturally, everyone interested in maximizing the realization of the human potential will be interested in the transformation of childhood gifts into adult creative work. In my own research I have been mainly concerned with understanding how such extraordinary adults do their work (Gruber, 1981e). It seems self-evident that such an understanding is necessary for understanding the transformation, early gifts to creativity – from now on I will abbreviate that phrase as T(G to C).

But even if we could be there to record every millisecond of it, we could not read off what we want to know directly from a moving picture of the creative life. All developmental processes are constructions of the scientific imagination.

In part, my emphasis on beginning with clear-cut cases of creative lives is a heuristic and methodological one: then at least we are studying the genuine article, and we can with some confidence in the pertinence of our efforts press our research as far back in the developmental history as possible. But in part my emphasis on approaching the study of giftedness through the study of creativity is intended to raise a question about the value of the concept of giftedness. Only if we can construct a plausible picture of T(G to C) is the concept of giftedness useful. If we neglect the outcome of an extraordinary developmental process, the whole investigation may be built on sand. What could it possibly mean for someone to be gifted if it does not imply something about the later course of development?

Of course, we already know that the relation between giftedness and creativity is an elusive one. Some, probably most, precocious or extraordinary children do not become creative adults. And some, possible many, adults who do creative work were not, on the available evidence, precocious or exceptional children. So research starting at the childhood end of T(G to C) and working forward in time is bound to produce many errors of both kinds.

Starting at the other end has as its main risk the tendency to draw too long a bow, in trying to infer remote origins from later conduct. But if we avoid this pitfall, when we study a creative life known to us through adult performance we cannot fail to be examining a phenomenon that is some part of the T(G to C).

Although our ability to predict a creative life from early performance is, to say the least, limited, there are certain distinctions we recognize easily among adults. For example, although it brings me up short, I understand what is meant by "B is more brilliant but C is the more creative." Speaking of adults, we might describe one person as gifted or talented and another as creative or productive. In other words, we have intuitive ways of distinguishing between the conception of ability at a high level and the conception of what the person does with it.

It has always seemed to me that Thomas Huxley was more brilliant and versatile than Darwin. Certainly, any fellowship awards committee comparing young Huxley's plans when setting out on the voyage of the *Rattlesnake* (1935) with young Darwin's plans when setting out on the voyage of the *Beagle* (Darwin 1934)—both wrote them down in a page or so—would have given first place to Huxley and put Darwin on the waiting list.

Both men, of course, led highly creative lives. Yet we have no question as to which one transformed biology and humanity's image of itself. When Huxley finally heard about the theory of evolution through natural selection, he exclaimed, "Why didn't I think of that?" He might well ask, and so might we. Even if our answers can be only speculative, of one thing we can be reasonably sure, it was not Darwin's greater brilliance that made the difference.

My belief is that Darwin and Huxley had fundamentally different views of science and of nature, and that for the task at hand, waiting for someone to take it up, young Darwin's vague and open receptiveness was a better beginning than young Huxley's hard-edge analytic objectivism, bordering on an early form of positivism. It is a pity that cognitive psychology has provided us with so little guidance as to the relationships among such broad ideologies or points of view and the conduct of a creative life.

The best discussion I know of this openness of Darwin's is *Beyond Anthropocentrism*, by Elisa Campbell (1983), a student of English literature. In *Darwin on Man* I stressed the importance of point of view as against mere problem-solving ability, and even included a chapter called *A Family Weltanschauung*. But I did not hit on this particular aspect of cognitive style, which is also captured in Evelyn Fox Keller's recent biography of Barbara McClintock, *A Feeling for the Organism* (1983).

If we want to understand the transformation of early gifts into later creative work, it might be helpful to compare individuals who are very good at something with others who are extraordinary—the merely gifted versus the extraordinary. At least then we would know that we were comparing people who can all do the kind of work being considered, and do it very well. There are possible flaws in this line of reasoning, but the comparison could hardly fail to be instructive. Do they employ the same processes? If not, what are the differences? If so, then what does account for the disparity in level of achievement?

In most domains it is well nigh impossible to make meaningful comparisons of this kind. But the world of chess has a highly developed system for rating the strength of each player. This permitted the Dutch psychologist DeGroot, himself a chess player with an expert rating, to compare the play of six grand-masters, four masters, and twelve who were rated either expert or second-class players (DeGroot, 1965).

They were all at least excellent, the weaker players having won a number of regional and national tournaments. Presenting each player with a series of chess positions to pursue, DeGroot elicited loud-thinking protocols. In one set of comparisons between five grandmasters and five experts, there was no question about it: The play of the former was far superior to that of the latter. But, astonishingly, DeGroot could detect no fundamental differences in the processes employed by the two groups.

Then what makes the difference?

Although the main aim of DeGroot's rich work is to understand the cognitive processes involved in high-level chess, when it comes to answering this question, over and over he puts major emphasis on matters of motivation and character. The grand master has lived the game with a greater passion, and has gone through at least one period of youthful chess monomania. As a result, he simply knows more chess: He has a richer knowledge base to draw on, and has it more readily accessible to him. This makes him both faster and more powerful. But this deeper knowledge of the game is the fruit of thousands of hours of play and study. If the grand master has a greater gift than the master, it is not a photographic memory or other magic, but is rather the *Sitzfleisch* and passion necessary to spend those hours.

DeGroot's picture of the development of chess champions may help to explain the high frequency of excellent chess players in certain populations, such as Russian Jews, in which culturally sustained attitudes lead often to early exposure, encouragement, and, above all, taking the game very seriously. (When I was a child, but by no means a chess prodigy, I was the only person permitted to play chess with my Uncle Sam, an expert. He had a bad heart, and any more serious challenge was considered dangerous to his life.) But we need not suppose that the emergence of such patterns necessarily depends on long-established ethnic or family traditions. In Indianapolis, Robert Cotter, a fifth-grade science teacher in an inner-city elementary school, organized a chess club for the students. A chess team emerged, disciplined and hardworking, willing to lose again and again in tournaments, and go back again. Three years later this all-black team won the U.S. national elementary school championship. In one year, four of their players were ranked nationally among the best fifty players under the age of thirteen. As one child put it, "It was the only sport here" (New York Times, May 10, 1983, p. 16).

DeGroot cites approvingly and at length a study of young composers by Bahlke, in which biographical evidence lent support to the

> "rational" view, contradictive to such "irrational" conceptions as an effortless "growth" toward mastership, inborn genius, unanalyzable, miraculous inspiration, magical intuition, and so on. He showed the prime importance of the factor of self-organization both in the developing composer's creative production proper and in his antecedent learning processes. Here, too, a very strong long-term motivation towards self-development in the field in question leads to a rapid accumulation of fertile, differentiated "experience." Instrumental, even indispensable, are the self-organized work and intensive training of the composer's early years. Even to an unparalleled genius like Mozart, it was by no means the gods who presented him with the gift of composing: he too had to acquire his system of creative methods bit by bit. (DeGroot 1965, 348)

Recently one of my students analyzed two series of string quartets composed by Mozart, the first in 1773 when he was seventeen years old and the second, begun after a lapse of nine years, from 1782 to 1785 (Leresche 1984). Both series were immediately preceded by the appearance of string quartets by Haydn, and both owed much musically to him. The first series are imitative, well schooled, formal, and a little dull. The second series – richer, more subtle, and more flowing – was begun shortly after Mozart made his personal discovery of Bach, whose music he then studied with ardor.

Mozart dedicated the 1782-85 quartets to Haydn, and wrote to his friend and master a letter openly acknowledging his debt, avowing that Haydn was "the father, the guide, and the friend" of these pieces, Mozart's "sons," whom he commends to Haydn for protection. Thus, like other young men leaving adolescence behind, when Mozart had grown musically independent of his older model, and had the time to assimilate other influences into forms that were more and more "Mozartish," then he could acknowledge his origins with gratitude.

This incident is of interest to us because it shows development on two timescales (within the earlier series, i.e., within a two-month period of work, and between the two series, i.e., over a twelve-year period). It shows also the way in which a creative person assimilates external influences to increasingly personal structures, and the differences between a gifted youth and a mature composer. Finally, it shows how these changes come about through the work the person does.

If we are looking for an agent with the transformative power required for T(G to C), we should look at the process of the creative work itself. Through being creative we become creative. Through struggle we become capable of struggle. Why does the first sound like a tautology, the second not? They are the same!

## THE TIME IT TAKES TO THINK

"By thinking on it continually." This was Isaac Newton's reply to the question of how he had discovered the law of universal gravitation (Westfall 1980b, 110).

We are tempted to see the achievement of the creative person as miraculous, in part because we do not take account of the extraordinary amount of effort and time that goes into the work itself and also into the self-constructive activity that makes the work possible. This is an understandable failing. Thinking is such a private activity. Even when recorded traces are left, as in scientific notebooks or artists' sketches, it takes almost Herculean labors of interpretation to relate these traces to the finished product. Moreover, as I have shown in a study of insights remembered, the creative person in his retrospective accounts necessarily telescopes events drastically (Gruber 1981e).

Nevertheless, if we want a picture of the growth of creative work, that is, T(G to C), we need some idea of the actual time it takes to think creatively and also of the time and effort necessary to effectuate an important change in the equipment the creative person brings to the work. We can get some idea of the first point by looking at creative lives. The second point is probably more amenable to experimental investigation.

There is no more reliable fact in the study of creative lives than this: Important creative achievements result from prolonged work, from protracted and repeated encounters of the creative person with the task he or she has undertaken. Consider a few examples, some of which are dealt with in greater detail elsewhere in this paper.

William Gilbert, preeminent pioneer of the experimental method, and founding father of the study of electricity and magnetism, worked eighteen years to produce *De Magnete* (1958), at the age of sixty.

John Milton conceived of a first provisional plan for his masterwork in 1640. He resumed work on it in 1658 and finished *Paradise Lost* seven years later, at the age of sixty-six (1667).

Isaac Newton, in his "annus mirabilis" (actually, the two years 1665-1666) began the work in mathematics, optics, and mechanics and gravitation that became the part of his lifework for which he is still almost worshiped. In spite of Newton's faulty recollections in old age, modern studies of the manuscripts show that it really took him the next twenty years to move from these preliminary sketches to *Principia Mathematica* (1687), which he wrote and published over a two-year period, when he was forty-five years old.

Charles Darwin became a professional naturalist during the five-year voyage of the *Beagle*, began the search for a workable theory of evolution soon after returning home, and in about 1 1/2 year's work fashioned the outlines of the theory of evolution. Twenty-one years later he wrote and published *On the Origin of Species* (1859), at the age of fifty.

Sigmund Freud, from boyhood interested in dreams, made the decisive turn away from somatic medicine when he went to Paris to study with Charcot at the age of thirty. Ten years later, in 1891, he began the work that led to his founding masterwork, *The Interpretation of Dreams,* when he was forty-three years old (Freud 1955).

Even the seeming counter-examples of astonishing early achievements display this character of prolonged work. Einstein was only twenty-six in 1905, and that year he wrote and published six finished articles, each of them fundamental, two of them expounding the theory of special relativity. But he had been thinking about the issues for some ten years. In 1895 at the age of sixteen, he had written a paper, *On the Examination of the State of Aether in a Magnetic Field*, which he sent to an uncle in Belgium, but which was never published. The same year, he conceived of his now celebrated thought-experiment: What would happen if the observer ran after a light wave with the same velocity as the light itself? In the intervening years leading up to 1905, he continued to think about related questions in an increasingly sophisticated way (Pais 1982, 130-132; Miller 1981, 123-135).

Mozart's precocity as a performer and composer is not in question, but, as we have seen, this is not to say that his adolescent compositions were highly creative. When I was writing *Darwin on Man* (1981e), at one point I faced a very specific problem. There were several important early notebook entries that could not be reliably dated: Had such and such a thought occurred to Darwin in 1835 or 1836? Or this other idea in 1836 to 1837? On the basis of the evidence available to me, and a hard-won feel for the subject, I made my best guesses, and am glad to say that they have been confirmed by subsequent research (Sulloway 1982c). But the more important point is this: From the point of view of the psychology of thinking as it stood then (and now too, I fear), the decision as to dates made absolutely no difference. For my purposes, to reconstruct the major episodes in a thought process, accurate knowledge of sequence was enough. But we have very little information about rate, nor even any good reason, explicitly stated within a theoretical framework, why we should seek it. We have some picture of the rapid, intuitive, perceptlike processes that take up to a few seconds; we have a rather different picture of the tactical and strategic exploitation of means and ends in problem-solving episodes that take ten minutes to an hour; and we have still another picture of the much slower processes, like the growth of the self-concept or the evolution of purpose, that take years and decades. But we do not have any theoretical apparatus for distinguishing problem-solving processes on the one-hour time-scale from those on the one-year time-scale.

For example, in forming a plausible and correct impression of such widely cited moments of insight as Poincaré's celebrated account of mathematical thinking (1952), it is important to insist that this occurred in seven distinct episodes in different places over a period of several months, and not in one blinding flash as he stepped onto a bus (Gruber, 1981e). But suppose it had been days rather than months: How would that affect our understanding of Poincaré's thinking? Or suppose Darwin had first been struck by some ornithological anomaly in 1835 rather than 1836? In either case, the "remainder" of the thought process (that is, most of it) in question took many more months, and our present-day cognitive theories cannot distinguish between one and fifteen months.

Insofar as it takes time to develop the kind of collegial relationships necessary for mutual aid, it might be important to know that Darwin became a convinced evolutionist in 1836, after certain important contacts with the ornithologist John Gould. Placing the event in 1835 (the *Beagle* voyage coming to an end) would make Darwin's thought a much lonelier, unaided process. Similarly, insofar as level of aspiration and estimate of self-worth are important in making great plans, the timing of events may matter. Darwin's undertaking a cosmic resynthesis of all biological knowledge *after* receiving an enthusiastic welcome and respectful recognition upon his return from the voyage is different from choosing the same task *before* this boost.

But notice, this argument of the preceding paragraph makes no cognitivist claim about the time it takes to think. It deals rather with some ideas about the construction of social relations and of the self, and of their import for creative work. Cognitive psychology, at this point in its history, is still almost indifferent to time.

This indifference emerges dramatically when we consider the time-scale of the typical laboratory experiment as compared with the time that goes into training and practice in real creative lives. The differences lie in the range between one and four orders of magnitude—between tenfold and ten thousand fold. Anyone who thinks we can simply extrapolate from one scale to another should read *Powers of Ten* (Morrison and Morrison 1982). So should everyone else. In other words, the great mass of experimentally gained knowledge may be very little pertinent to the study of creative lives.

The gulf, however, may not be unbridgeable. We cannot and would not want to reenact a creative life in the laboratory. But we can fairly easily scale up an experiment from about one hour to one-hundred hours per subject, and when we do this we begin to see profound transformations in the function being studied. Of course, such large methodological changes do not come free. Important compensatory changes, in the number of subjects and in the degree of standardization desired, must be permitted in the design. But we still have investigations that we can recognize as bona fide controlled experimentation.

At the biographical level, I do not know many good examples describing this sort of concentration of effort—ranging from the very persistent to the monomaniacal—except in the fields of athletics and the performing arts. Detailed accounts would make for rather dry reading. But Freeman Dyson's account of an adolescent summer spent teaching himself calculus is a good case in point (Dyson 1979). If interest in this subject grows, we will be able to accumulate a better picture of the process of concentration itself and of the social and familial supports it both requires and engenders.

## THE SHAPE OF A CREATIVE LIFE

In the context of a volume of giftedness it is difficult to shake off the stereotyped idea of a "normal" sequence for a creative life: precocity in childhood, early commitment and achievement, single-minded pursuit of creative goals, a lifetime of elaboration of these beginnings, eventual decline.

But a little consideration of a few cases will show how little grasp this schema gives us of the shapes of creative lives. Albert Einstein was not precocious, did not learn to speak until about three. William James was a lost soul until about the age of thirty, when his reading of the French philosopher Renouvier helped him to shake off a prolonged crisis of will (Perry 1948, 121). Neither Isaac Newton nor Bertrand Russell (each an author of a *Principia Mathematica*) was particularly "single"-minded. Each had "sidelines" that began early and took up something like half or more of his lifetime—in Newton's case, religion and alchemy, in Russell's, pacifism. Russell wrote his *Foundations of Mathematical Philosophy* while in Brixton prison for his antiwar activity during World War I.

Studies such as Lehman's *Age and Achievement* (1953) provide a different path into the discussion of the shape of a creative life. The field of mathematics is widely mentioned as proof par excellence of the importance of an earlier achievement for the later career. But one of England's most distinguished mathematicians, G. H. Hardy, himself quite an elitist, in his provocative book *A Mathematician's Apology* (1941), claimed that he had not reached the height of his powers or done his best work until his forties.

A careful reading of the main source of information, Lehman's work, shows how weak is the support of this stereotype. Lehman took his data from Cajori's *History of Mathematics*. He plotted the total number of contributions against age of first important contributions to mathematics for 444 mathematicians. Lehman concluded, "Mathematicians will be interested to know that the correlation ratio between these two variables is -.61, which means that the earlier the age of beginning, the greater the total number of contributions" (Lehman 1953, 185).

As every graduate student knows, a correlation of .61 accounts for only about one-third of the variance. Moreover, Lehman's scatterplot suggests that a small number of cases accounts for most if not all of the correlation. Eliminating about from extreme cases from each end of the scatterplot would reduce the correlation to almost zero. Much the same could be said for Lehman's scatter plots of the same variables for chemists and physicists.

It should be added that people who start late and therefore make only one or two important contributions actually provide evidence against the early-start stereotype under discussion. There are in Lehman's scatterplot six mathematicians who "began" past the age of seventy and made only one significant contribution to mathematics. Pumped uncritically into the scatterplot, they account for much of the correlation, and seem to add credibility to the stereotype. Yet their lives testify against it.

Still, something is probably gained by the knowledge that there is some low correlation between the age of beginning and number of contributions. It might conceivably mean that an "innate" gift that finds early expression will continue to do so. On the other hand, it might reflect the way in which a person shapes himself and the road he will take. In psychological development as in embryological, first steps in one direction are fateful for whatever is to follow. This is the meaning of Maruyama's phrase "initial kick" in systems that can evolve in different directions, in his paper with the wonderful title *The Second Cybernetics: Deviation-amplifying Mutual Causal Processes* (1963). It is also the meaning intended by Robert Frost's poem *The Road Not Taken*.

The emphasis on quantitative analysis in studies of age of achievement leads to some peculiar omissions. A case in point is John Milton. To examine the age of achievement in literature, Lehman compiled a table of the sixteen most prolific contributors to English literature, again arguing for the relation between age of first contribution and total number of contributions. It is certainly a good list, headed by Shakespeare and also including Dryden, Bulwer-Lytton, Shelley, and Defoe. But Milton's name is missing. Presumably, had he not spent so much time in politics, he would have been more prolific in poetry. My encyclopedia says, "Had Milton died in 1640, when he was in his thirty-second year, and had his literary remains been then collected, he would have been remembered as one of the best Latinists of his generation and one of the most exquisite of minor English poets" (Masson 1911).

This article goes on to give one of the best short accounts I know of a creative life in which different enterprises take center stage at different times. Masson explains the functional relationship among such waxings and wanings, defending Milton against those who feel he "deserted" literature for politics.

Not so, says Masson, his pamphlets are great literature, and moreover, without this twenty-year interlude he would not have formed of his life the "true poem" necessary for him to write *Paradise Lost*.

More dramatically, his greatest work, *Paradise Lost*, would never have been written had Milton (Cromwell's champion and secretary for foreign affairs) not escaped the scaffold at the Royalist Restoration after Cromwell was deposed and executed in 1658. Milton had begun work on *Paradise Lost* in about 1640, put it aside and resumed it in 1658, and finished it in 1665 when he was sixty-six years old.

Although Milton's masterwork was written in his later life, he was hardly a late bloomer. The poetry he wrote before the age of forty stands as part of the treasure of English literature. His contemporary, John Locke, however, first studied and practiced medicine, and then participated vigorously in political life as secretary to the earl of Shaftesbury. Only in 1666, when he was thirty-four years old, did he write a significant philosophical piece (the *Essay Concerning Toleration*). It was not until four years later, and then almost by chance, that he found the road that led him eventually to his masterwork, the *Essay Concerning Human Understanding* (Locke 1965), which appeared in 1690 when he was fifty-eight years old.

In a good English tradition, Locke did much of his philosophical thinking and writing, including the *Essay*, while on the run from the British government. He spent the years 1683-1689 in Holland, and there completed the *Essay*. This work should be considered one of the founding documents of cognitive psychology, but the unity of its author's life would not stand well with today's exponents of a bloodless, depoliticized, decontextualized cognitive science. Locke was as much concerned with the political philosophy of human freedom as he was with the way people think and get knowledge when they are free. It is, incidentally, a gross distortion of the history of ideas to shrug off Locke as an exponent of the passive receptive mind entailed in the metaphor of the tabula rasa. That was only his way of saying that ideas are not inborn but come through active experience. Another metaphor he employs for the getting of knowledge captures the spirit of his intellect more aptly: The knower is a hunter, a falconer who sends his bird out to the hunt, to bring back the prey of truth ("Epistle to the Reader," with which the *Essay* opens).

Another figure who found his way rather late is Sigmund Freud. There are few if any indications of very early precocity in his biographies. There was at least one moment of early revolutionary activity: At the age of seven or eight he deliberately urinated in his parents' bedroom (Jones 1953, vol. I, 16). And there is one account of early recognition: In a casual encounter, Freud's father exclaimed to a child who was arguing with his father, "My Sigmund's little toe is cleverer than my head, but he would never dare to contradict me!" (Jones 1953, vol. I, 19).

It does seem that sometime between the ages of eight and ten young Freud was "turned on" to the life of the mind—beginning the interest in language, literature, and antiquities that eventually made him not only a great psychologist but a great writer. As is well known, his early medical studies took him in the direction of neurology and pharmacology, in which fields he made promising research starts. It was not until 1885 (age twenty-nine) that he made his fateful visit to Paris and worked with Charcot for six months. Ten years later, after a complex gestation, he began to write the work that may be his most important (he thought so), *The Interpretation of Dreams* (Freud 1955), finished and published when he was forty-three.

Freud's life brings home the point that a person leading a creative life need not crash the scene like Gangbusters. Some great figures find their way slowly. Freud put it well: "The voice of the intellect is a quiet one, but in the end it will be heard." His life also demonstrates great integrative powers. His deep knowledge of language and the classics formed a preeminent part of his psychoanalytic theorizing. His neurological training played a vital, if sub-rosa, part in his psychological thought (Sulloway 1979).

I hope the reader understands by now that I am not questioning the occurrence of precocity, early achievement, and single-mindedness in creative lives. Of course they occur in some cases, and sometimes even all three of them together. But I am questioning both their necessity and sufficiency for the evolution of a creative life, and also their aptness, when taken together, as a syndrome for characterizing the typical course of creative growth.

Much of our discussion up to this point has centered around questions of time—the time that goes into practice, the time needed to create a great work, and the age of achievement. All these are separable but connected issues. The different sorts of evidence I have assembled are meant to show that the time required is long. Perhaps this is the true meaning of the expression "Ars longa, vita brevis." This disparity exacts of the creative person that he mobilize himself for his tasks. Any discussion of T(G to C) must deal with that process of self-mobilization.

## SELF-MOBILIZATION AND THE FEELING OF SPECIALNESS

"I am different, let this not upset you." I was in graduate school when I first knew these words of Paracelsus, and I relished them. Ten years and a war earlier, as an undergraduate, when I first studied the psychology of thinking by listening to Solomon Asch's lecture from the typescript of Max Wertheimer's *Productive Thinking* (1945), Paracelsus would have seemed strange to me. We learned to approach creative thinking as nothing but problem solving, albeit informed by the sensitive grasp of structural change inherent in *Gestalttheorie*. The proper and productive attitude toward the problem confronting the thinker was "task-oriented," and heaven forbid an errant "ego-oriented excursion." What could be more reasonable, it seemed then: If you want to think well, surrender yourself to the task, become engrossed in it, respond to the structural requirements of the situation. If we had thought of creativity as a characteristic of a person, we would have thought of it as the capacity for just such task absorption.

There is a small historical paradox here. It was the Lewinian offshoot of *Gestalt-theorie* that fostered the distinction between task- and ego-motivation (also known as intrinsic and extrinsic motivation, although there are different shades of meaning involved). Yet it was the same Lewinian ethos that produced and vigorously pursued the fruitful concept of level of aspiration (Lewin 1935), which gave rise to an interesting experimental literature. It should have provided the hint necessary to see that in real life, attacking the most difficult tasks requires the highest level of aspiration, and consequently puts stressful demands on the ego system.

History aside, it seems to me now that we will never have an adequate theory of creative work unless we come to understand exactly how the creative person moves back and forth between these two attitudes, both surrendering himself or herself to the requirements of the task and mobilizing every personal resource to surmount its difficulties. For we are not speaking of tasks that present themselves politely, visiting card in hand, but of life goals that the creative person shapes and assumes, a set of special requirements few others feel. We are speaking also of estimates of one's own powers that lead the creative person to attack the almost impossible, the formerly undreamed of, the question of questions.

To the person doing creative work, once on the road, such choices need not feel at all like arrogance. He or she is not a stumblebum. It is part of the metier to have some grasp of the historical situation and a realistic estimate of available personal resources, in short, the self and world knowledge necessary to move purposefully and effectively in a direction.

The development of a self-concept adequate for creative work must include:

1. A grasp of the disparity between the actual and the possible, and the visionary spirit necessary to treat the latter as more real than the former—to dwell in the world of the possible.
2. A sense of special mission; a will to commit enormous energies and all the time necessary, a lifetime, to the chosen task.
3. A sense of daring, a high level of aspiration—*The Courage to Create*, in Rollo May's words (1975).

If the creative person does not knowingly set high and difficult goals, then we would have to think of him as moving blindly toward his achievements. There are potentially a few such examples to consider. At least two of Darwin's contemporaries, Algernon Wells and Patrick Matthews, hit on the idea of natural selection. But they were not interested in exploiting it, did not see its importance, did not think of themselves as special individuals trying to transform humanity's image of itself and its origins. So the name you recognize is Charles Darwin — and, of course, Alfred Russel Wallace, who was also consciously searching for a theory of evolution.

I have assembled a few examples of clear expressions of this sense of specialness and high purpose. They occur at different moments in the life history and illuminate different aspects of the construction of self in the creative person.

Newton, in a famous remark, said, "If I have seen further it is by standing on the shoulders [sic] of giants." Since he said it in connection with a dispute over priorities, one of several, with Robert Hooke, Manuel (1979) has suggested that it was Newton's not so subtle way of casting aspersions on his physically crooked and dwarfed rival. With or without the note of spite, it was a less than modest remark. Newton certainly did not think of himself as a pygmy on the shoulders of giants (although that was probably the original form of the metaphor). His high level of aspiration is reflected in a less disputatious remark: In the first two books of *Principia*, he wrote, he had "laid down the principles of philosophy ... It remains, that from the same principles, I now demonstrate the frame of the System of the World," (Book 3 of *Principia*, cited in Andrade 1950, 83).

Darwin, too, left no doubt as to the cosmicality of his aspirations. One example will have to do. A few months after he began his first notebook on evolution, he wrote a summary of the progress he had made. I select, from a context that is mainly "task-oriented" and focused on the specific tasks of constructing an evolutionary biology, a few phrases that suggest Darwin's level of aspiration:[1]

> "Before attraction of gravity discovered it might have been said ..." (B Notebook, p. 196, Darwin manuscripts in Cambridge University Library). Here follows an analogy between his own and Newton's tasks.
> "... My theory very distinct from Lamarck's" (B Notebook, 214). This is one of several passages where he compares himself with his precursor and rival.
> "The grand question which every naturalist ought to have before him when dissecting a whale, or classifying a mite, a fungus or an infusorian is *What are the Laws of Life?*" (B Notebook, 229). Darwin knew only too well that this was not the attitude of his contemporaries.

Darwin made those remarks in a notebook written in his late twenties. But he kept the same spirit throughout his life. For example, in 1856 (aged forty-seven) he wrote to a colleague, "I have lately been especially attending to Geograph [ical] and Distrib [ution], and most splendid sport it is,—a grand game of chess with the world for a Board" (letter to Charles Bunbury, April 21, 1856).

Freud, in several places, likened himself to Copernicus and Darwin in revolutionizing man's image of his place in the world: His planet was not at the center of the universe, his species was not at the pinnacle of creation, and his rational mind was not in control of itself: a Miltonic triple dethronement and five-century revolt of the angels against the order of heaven, with Freud himself leading Satan's legions into the twentieth century.

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1. All citations from the Darwin manuscript are based on my own reading of them in the Manuscript Room of the Cambridge University Library with the help of my collaborator, Paul H. Barrett. These quotations can also be found in *Darwin on Man* (Gruber 1981e).

Einstein, whom we rightly know as a modest man, in 1905 wrote to his friend Conrad Habicht, "I promise you four papers ..., the first ... deals with radiation and the energy characteristics of light and is very revolutionary." He goes on to describe the other papers, the last of which is the first article on the special theory of relativity (Miller 1981; Pais 1982).

Whichever of the six (not four) fundamental papers he wrote in 1905 was the more revolutionary does not concern us, only the evident fact that he did not mind the role, that he saw himself as the person whose thinking would transform physics.

I do not mean to suggest with these examples that these people were all arrogant or immodest or unduly preoccupied with the greatness of their goals. On the contrary, they managed very well to *harmonize* their personal needs and the historical requirements of the situations that confronted them. Nor do I mean to suggest that they had similar personalities. With regard to the go-needs under discussion, they each handled matters very differently. In his priority disputes with Hooke and others, Newton was bitter and fierce, and then sometimes willing to back down a bit, but still leaving much rancor. Darwin avoided a potential dispute with Wallace by asking a group of distinguished scientists (all of them his friends) to mediate, and as I have written elsewhere (Gruber, 1981e), they did so quite satisfactorily for all concerned. Freud worked more closely with others, and simply threw them out of his circle as need be to maintain unity, always a great blow to those father-figure followers. Einstein may have been a bit above it all. If Darwin was the most human of this lot, Einstein was the most saintly.

## CONCLUSION

The issues I have been raising here are not arbitrary or idiosyncratic intrusions in a discussion of human extraordinariness that otherwise has a clear rationale to justify it. They are necessary considerations.

If the concept of giftedness is to be taken seriously, a gift must have as its consequence some connection with extraordinary achievement.

If the transformation of a gift into a creative achievement is to be understood, the end point of the process must be studied as an integral part of improving our concept of giftedness.

If the creative person is identified by his unique achievements, scientific method must be adapted to fit it for the study of unique events, or the project must be abandoned as standing beyond science.

If creative achievements are rare and unique because they are difficult, complex, and improbable, then they must take time in their construction.

If protracted purposeful work is essential to creative achievement, the creative person must be capable of it, having not only the skills of his metier but also the sense of purpose, ego strength, and other personal resources necessary to sustain the effort.

If creative achievement depends on such combinations of purpose, self-mobilization, and skills, then the study of creative work requires the study of such unique personological configurations in action.

The shaping of a creative life is not an a priori gift but a process of self-construction.

# GIFTEDNESS AND MORAL RESPONSIBILITY[1]

## *Creative Thinking and Human Survival*

> To struggle against war is therefore to act according to the logic of life against the logic of things, and that is the whole of morality. (Piaget, 1918)

### THE COUNTRY OF THE BLIND

The gift of Midas brings him to grief, for if everything he touches turns to gold, what is there to eat or drink, whom to caress? The escape route from Plato's cave is not taken. The long-enchained inhabitants of the grotto do not wish to see the world outside. The explorer's journey has been in vain. The erstwhile liberator is killed. A great gift is futile when its owner is not appropriately connected to the world.

This is also the theme of a number of H. G. Wells's stories. In *The Invisible Man* (1897), the person with an extraordinary gift moves in an ordinary world, which defeats him. In *The Country of the Blind*, an ordinary person finds himself in an unusual world (Wells 1911). It is the person-world connection that must be appropriate. The meaning and value of a gift depend on that relationship. To understand it, we psychologists must study both person and world.

In the country of the blind, so the saying goes, the one-eyed man is king. Not so, says Wells. In the fable he creates, a sighted person falls into a forgotten valley, where all the people are blind. He sees his opportunity. Here he will be king and master. But the people have mastered the world they live in, and they do not understand his. They defeat his aspirations. As they are kind, they wish to make him one of them. Their skillful surgeons propose to cut away those worse than useless pulpy fluttering malformations he calls eyes.

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1. This chapter is an outgrowth of the Conference on Research Needs in the Study of the Development of Extraordinary Moral Responsibility, held at Yale University, November 10-12, 1983. The Conference was jointly sponsored by the Social Science Research Council (SSRC) and the Bush Center for Child Development and Social Policy of Yale University. I thank Peter B. Read of SSRC, Edward Zigler, Director of the Bush Center, and David Feldman. Chairman of the SSRC Committee on Giftedness and Creativity, for their cooperation. I especially acknowledge the collaboration of Sam Nash of the New Haven Board of Education in organizing the Conference and the participation of David Bakan, Michael Basseches, Ann Colby, William Damon, Henry-Lewis Gates, Carol Gilligan. Edmund W. Gordon. Aaron Hershkowitz, Martin L. Hoffman, George B. Hogenson, Robert Holt, Sharon Lynn Kagan, Georg Lind, Fayneese Miller, Bruce M. Russet, Victor Saraiva, Gloria Small, Robert J. Steinberg, Elliott Turiel, Doris B. Wallace, and Helen Weinreich-Haste. I take sole responsibility, however, for the ideas expressed in this chapter.

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My first goal in this chapter is to examine the concept of moral responsibility. Is there a domain of moral responsibility on which someone might be gifted or creative that might have the same epistemological standing as, for example, the domain of mathematics or music? How does moral responsibility differ from moral judgment, which has been the main target of investigations in the field of moral development? Is it helpful to think of this domain as being located in a social-historical space rather than in the individual as Feldman (1980) has suggested for other domains? Or is it more useful to think of moral responsibility as a frame of mind or special sort of intelligence of the kind that Gardner (1983) has recently proposed? Does it make sense to say that some people are morally gifted?

My second goal is to raise some questions about the relevance of moral responsibility to all gifted and creative individuals. Does being gifted or creative impose a special moral responsibility on an individual? Does it equip him or her better to handle both normal and special responsibilities? Do gifted and creative people feel such moral responsibility? How does moral responsibility develop?

All statements about what *ought* to be done imply that something *can* be done. When one steps outside of well-charted, rule-governed situations, what ought to and can be done can only be discovered by persistent creative efforts. Such efforts must necessarily be made within some framework and be governed by some point of view (see Gruber 1985c).

In this chapter I describe some individuals who have acted within the framework of the Judeo-Christian ethic, placing primary value on human life, condemning mass destruction of human populations as immoral, and treating the survival of the human species as one of a small number of ultimate goods. I describe these individuals in order to clarify the general idea of extraordinary moral responsibility. This choice does not imply that any specific formula exists for deciding who is morally responsible.

Having made the distinction between moral reasoning and moral responsibility, it remains for psychologists to discover how to identify and nurture the gift of extraordinary moral responsibility. It will be important to do so in forms that respond to the great moral issues of our age, among which the greatest is the prevention of a nuclear holocaust. It might be said that this statement is a value judgment and has no place in a scientific discussion of giftedness and creativity. Let me address those two points separately.

First, of course it is a value judgment to say that preventing a nuclear holocaust is society's greatest moral issue. But calling the statement a value judgment is an inappropriate response and betrays what clinicians call "inappropriate affect." Consider the statement, "The Nazis should not have killed six million Jews." That is a value judgment, but no one says so because the values in question are universally accepted.

Second, in doing scientific work, researchers try to free their statements from the constraints of any particular set of values, in large part by becoming more aware of their own points of view, always searching for wider, more universal frameworks in which to house their knowledge. At the same time, no one can escape his or her personal construction of the historical context in which he or she lives. Every great scientific idea that is now universally accepted—the nature of heavenly bodies, the shape of the earth, the origin of species—has passed through a period in its history when it seemed to be primarily a moral question or to be inseparable from moral questions. Looked at in this historical perspective, the feeling that something is a value judgment, rather than disqualifying it as a scientific issue, might rather be a good clue that here is a promising problem for us to tackle.

For my own part, I write from within the framework of the same ethic that impelled the young Piaget to write, "To struggle against war is therefore to act according to the logic of life against the logic of things, and that is the whole of morality" (Piaget 1918a). I do not try either to escape from or reexamine that framework. But I do recognize that the idea of extraordinary moral responsibility, as distinct from moral reasoning, is relatively new to and unexplored by psychologists. Exploring the idea brings into prominence questions about the relation between value systems and the study of giftedness and creativity.

Psychologists who have written about moral development have been concerned predominantly with how a good person reasons about moral issues, not about how a good person acts to make a better world. Is the first kind of morality more "psychological" than the second? In spite of its subtitle, *The Changing Status of Children: Rights, Roles and Responsibilities*, a special issue of the *Journal of Social Issues* is almost entirely concerned with what adults can do for children. Only one author, Takanishi (1978), mentions an alternative conception of "children as redeemers of the social order." Must each person go through a long period of unalloyed dependency, growing up to taking responsibility only upon reaching young adulthood? Are there perhaps some morally precocious young people who need not or cannot wait so long? If they exist, how would a developmental theory of giftedness and creativity apply to them? My old copy of the Boy Scout Handbook quoted the Athenian Boy's Oath, "to leave my city fairer than I found it." Contemporary editions omit it. Was that idea once appropriate for children, but not now?

In my own efforts to relate the fields of moral development and giftedness, and at the Yale Conference on Research Needs in the Study of the Development of Extraordinary Moral Responsibility, two different ideas have been considered: first, that there might actually be a domain of moral giftedness and creativity, and second, that creative achievement in other domains is related to the problem of moral responsibility as it is experienced by creative people.

Although the first idea engenders interesting discussion, there is considerable controversy about it and not even the beginnings of a research approach. Considering the amount of recent ethological literature on the phenomenon of altruism, it is at least reasonable to broach the question of whether a domain of moral giftedness exists. If stages of development in moral reasoning can be entertained as a plausible idea, then some people might be considered precocious in this regard; if moral responsibility were also somehow connected with maturity of moral reasoning, an argument in favor of the idea of moral giftedness would have a foundation. Rejecting the idea of moral giftedness might entail rejecting some of these presuppositions.

The second idea involves analyzing the relation between moral responsibility and giftedness. It seems reasonable and defensible to propose that a successful, creative person is in a good position to assume moral responsibility. He or she has proven ability in some domain and is a member of a special community that may be relevant to the moral issues at stake. He or she has earned some degree of eminence and influence that may actually make it possible to affect the course of events. For example, some of the physicists who were involved in the early development of nuclear weapons saw the moral relevance of their scientific work, and engaged in a prolonged search for ways of applying their special knowledge to some moral purposes. In the case of psychology, it seems evident that practically all modern thinking about war and peace, military strategy, and the possibility of peace is permeated with psychological assumptions. As a result, psychologists may be in a good position to use their professional knowledge and creativity to increase the chances of the survival of our species.

For these reasons, therefore, the way in which some scientists and other creative people become motivated to take responsibility for great social issues is itself an important psychological question. At one extreme, one might argue that giftedness is general and that a person who is creative in one domain ipso facto is well equipped to deal with great moral issues and, consequently, has the obligation to do so. Taking a more moderate position, one might argue only that a person who is creative in one domain is in a good position to assume moral responsibility, that sometimes he or she becomes aware of this possibility, and that it is incumbent upon psychologists who are interested in giftedness to understand how this comes about.

These are the psychological questions that underlie this chapter. I cannot hope to answer them all. I do explore them, and in order to help me, I discuss two groups of gifted and creative people. One group comprises those physicists who have been faced with the deep moral problem posed by their role in the invention of nuclear weapons, with special attention to their early responses in the 1930s and 1940s. In the other, I examine the idea of moral responsibility as it applies to the working lives of three distinguished psychologists: William James, B. F. Skinner, and Charles Osgood.

The choice of these subjects reflects a third goal I had in writing this chapter: to link the topics of morality and giftedness and creativity to today's imperative need to reduce the threat to the survival of our species. To some readers this may seem to be a far-fetched set of connections, and so I will deal with this issue before turning to the other matters.

## LINKING GIFTEDNESS AND CREATIVE THINKING WITH MORAL RESPONSIBILITY AND THE THREAT TO HUMAN SURVIVAL

### *Ecological Considerations*

There is now widespread agreement that psychologists must work out a more sophisticated understanding of the environments in which behavior and development occur. Brunswik (1956, 1957) gave this position its most profound examination. Recently, Bronfenbrenner (1977) has urged an ecological approach to developmental psychology.

There are two quite distinct ways in which the threat of nuclear war forms a part of our contemporary life space. First, nuclear war is an objective threat, attested to and agreed upon by experts of so many kinds and persuasions that it hardly needs documentation. Second, the threat is phenomenally present or subjectively real in the sense that information and discussion about it is very widespread in many sources of public information. In the press, the recent recognition of the danger of a "nuclear winter" has been widely disseminated. The film *The Day After* was shown on a national television network. The film *War Games*, shown in movie theaters across the country, depicts a gifted adolescent who, in playing with his computer, penetrates the most secure military computer network and comes close to triggering a full-scale nuclear war. It is to be expected that many gifted and creative individuals will be well informed about public concerns for the survival of our species. Even a Sunday newspaper supplement, *Parade Magazine*, carried Sagan's (1983b) analysis of the threat of a nuclear winter to 50,000,000 readers. Sagan and his colleagues have calculated that a moderate-scale nuclear war would throw up enough smoke and dust to screen out the sun's rays and produce a three-year period of darkness with temperatures throughout the northern hemisphere remaining steadily at about - 250C°. There is no way of keeping this kind of information from young people. A thoughtful youngster might justifiably wonder, "What is the point of cultivating my talents?"

In 1977 a task force of the American Psychiatric Association was formed to study "the psychological effects on children and adolescents of living in a world where thermonuclear disaster is a constant threat." One of the members, John Mack of the Harvard University Medical School summed up the results: "Children are aware of the threat of nuclear war and live in fear of it." He cited more detailed evidence of the way in which young people are shaping their life plans with these fears as a major consideration (Mack 1981). Lifton and Falk (1982) have also given an excellent account of the historical and developmental course of such fears. They concluded, "Questions arise among the young about adults' capacity to keep them, and the world, alive" (p.55).

*Attitudes toward Science and Public Policy*

It cannot be said that there is perfect agreement among psychologists that in their role as psychologists they should concern themselves with such broad issues. At one extreme, perhaps, is the position advocated by the *American Psychological Association*'s ad hoc Committee on Public Affairs, recommending that the wider the issue the less the *American Psychological Association* should do (Tyler 1969). Presumably, since the extermination of our species is the widest possible issue, it would get zero attention.

In sharp contrast to this is the position of *Psychologists for Social Responsibility*, an association that devotes most of its energy to involving psychologists in stopping the arms race. Three gifted and creative former presidents of the *American Psychological Association* are among the members of the Advisory Board: Jerome Bruner, Carl Rogers, and M. Brewster Smith. Later on in this chapter, I discuss the career of Charles Osgood, another gifted psychologist and former APA president, who has long made survival of the human species a professional concern.

It is not my purpose in this chapter to explain the behavior of all the individuals I mention. But in mentioning them I do want to establish a kind of "existence theorem": It is possible for someone to be an excellent scientist—or otherwise gifted and creative person—and still find time for steady, demanding involvement on behalf of what he or she feels is a moral responsibility, both inside and outside the domain of his or her creative work. Beyond the profession of psychology, there are other scientists concerned and willing to engage in the issue of human survival with all the aid possible of scientific and professional tools and organizations. For example, in 1982 an assembly of presidents of scientific academies and other scientists from all over the world presented a "Declaration on Prevention of Nuclear War" to the Vatican. After outlining the dangers, the Assembly appealed to scientists, to use their creativity for the betterment of human life, and to apply their ingenuity in exploring means of avoiding nuclear war and developing practical methods of arms control. To religious leaders and other custodians of moral principles, to proclaim forcefully and persistently the grave human issues at stake so that these are fully understood and appreciated by society (Conference on Nuclear Warfare 1982, 449).

Thus, although there is no unanimity on the issue, there is strong support for the idea that creativity and morality can be linked in scientific and professional approaches to eliminating the threat of species extermination.

There are many relevant historical precedents, but perhaps the most pertinent is the official American reaction to the Soviets launching the Sputnik satellite in October 1957, the first such achievement by any country. Admiration was coupled with dismay that our feared rival had stolen a technological march on us and had gotten ahead in science education. This event sparked a wave of expansion in science education and increased support for the education of the gifted. Social and technological change do sometimes beget changing psychoeducational needs, attitudes toward creativity, and decisions about the kind of creativity needed.

## THE IDEA OF MORAL RESPONSIBILITY

One does not read very far in the literature of moral development without rediscovering (a) that most of it is concerned with moral reasoning or judgment, not action (Weinreich-Haste and Lock 1983) and (b) that neither levels of development in moral reasoning nor any other verbal measures of morality are good predictors of moral action (Straughan 1983). Mischel and Mischel (1976) concluded that only about 10% of the variance in moral behavior could be predicted from tests of moral reasoning; obviously that limitation in predictive power runs in both directions.

It may be psychologically interesting to find ways of improving such predictions or, alternatively, of explaining the low values obtained. But scientists who feel some sense of urgency about facing the threat to species survival need to take another approach to studying the development of moral responsibility. It might help to identify and understand those unusual people who do want to be effective, who are morally responsible, rather than studying the typical course of development. In psychological research, a time-honored strategy for attacking a general problem is to study some atypical cases. To this end, let me first sketch a hypothetical, idealized, very full and demanding version of a morally gifted person who is faced with the threat of nuclear war. The ideal morally gifted person would exhibit the following four characteristics.

1. *Moral Reasoning and Universalism.* A morally gifted individual would have to exhibit the universalism that is considered to be characteristic of the higher stages of moral reasoning (Kohlberg 1973; Weinreich-Haste and Lock 1983). In some historical contexts there may be valid arguments, residues of cultural relativism, against insisting on universalism. But any universalist moral standard, such as "the greatest good for the greatest number," necessarily presupposes that species survival is an ultimate good. A morally gifted person who is facing the threat of nuclear war cannot escape recognizing that the fate of all humankind is joined: Nuclear winter for one is nuclear winter for all.[2]

2. Kohlberg described the higher stages of moral development as follows: "Postconventional, autonomous, or principled level. At this level, there is a clear effort to define moral values and principles which have validity and application apart from the authority of the group or persons holding these principles, and apart from the individual's own identification with these groups ... Stage 6. *The universal ethical principle orientation*. Right is defined by the decision of conscience in accord with self-chosen ethical principles appealing to logical comprehensiveness, universality, and consistency. These principles are abstract and ethical ... they are not concrete moral rules like the Ten Commandments ... These are universal principles of justice, of the reciprocity and equality of human *rights*, and of respect for the dignity of human beings as individual persons (1982, p. 282). It is noteworthy that in 1969 (when Kohlberg first made this statement), it was still possible to emphasize individual rights in formulating the universalist ideal of the highest stage of moral development. In 1984 the point that individual human rights presuppose the continued existence of humanity as a species has become salient. This transformation in the conception of the highest stage of moral development entails a corresponding change in the conception of moral giftedness.

2. *Cognition and Moral Responsibility.* A person cannot act in a morally responsible way unless he or she is well informed about the world in which action must take place. For example, the recently available information about nuclear winter makes much clearer the need for a universalistic ethic concerned with species survival as an ultimate good and as an indispensable criterion for moral action. The fact that no matter where the bombs explode, the fate of our species is the same, disposes once and for all of any application of "just war" doctrines to nuclear warfare. The person who does not know enough to understand this is simply not in the game and can hardly begin to be morally responsible.

   But knowledge is not enough. The person who is extraordinarily morally responsible in relation to the issue of nuclear war must be capable of living with the knowledge of potential horror, and of making it a basis for positive action. This kind of cognitive-affective control may be a rare trait; there is reason to believe that the more typical response to such knowledge is either repression or avoidance (Janis and Feshback 1953). In his study, *Imagining the Real*, Lifton (1982) has recently elaborated his idea of psychic numbing and applied it to the reactions of children and adolescents to the danger of nuclear war.
3. *Initiative.* A person who is morally gifted would take steps to resist the blandishments and distractions of everyday life in order to free energies for the cause in question. Being morally responsible means more than moral responsiveness, more than waiting at the ready for Kitty Genovese to cry out for help. It means envisioning a need, looking for something to do about it, and doing it.
4. *Moral Passion.* In the literature on moral development almost no attention is given to moral feeling, notwithstanding some valuable works such as those by Gilligan (1982) and Hoffman (1980). When cognitive psychology was being invented, in the century or so between the rationalist Descartes and the empiricist Hume (1960), everyone who wrote about the Understanding, including those two, stressed the impossibility of clear thought without strong passions. "The Reason is, and ought to be, the Slave of the Passions."

   In studying moral giftedness today, there is a special need for examining anew the relation between cognition and emotion. To be a morally gifted person requires having a commitment to prolonged, steady work. This simply cannot be maintained without continued access to the feelings that will sustain it. It is significant that when a wide array of leaders—relatively cool diplomats (George Kennan), scientists (Lewis Thomas), and soldiers (Field Marshal Lord Michael Carver)—speak of the threat of nuclear extinction, they speak with great emotion (see Kennan 1981; Thomas 1981). They do not "lose their cool," they use their warmth. For brevity, I give only one example—Carver's closing words in an article on no first use of nuclear weapons. Carver, who was Chief of the Defense Staff of the United Kingdom from 1973 to 1976, wrote, "no human being has yet faced the terrible decision of ordering first use of a nuclear weapon, when he knew that those against whom is to be fired can, and almost certainly will, retaliate in kind. Let us hope that no being will give that order. If he did, he would not be human" (Carver 1983).

In summary, a person who displays extraordinary moral responsibility has high levels of moral reasoning, concern for issues of great import, strong moral passion and courage, and a propensity to translate thought and feeling into effective action. This is a person who takes moral initiatives, rather than only responding to situations that are thrust upon her or him.

This description is intended as an idealization in order to clarify a concept rather than to describe accurately any actual person. Much of the rest of the chapter is an examination of a few individuals who may have approached this ideal in ways connected with the issue of war and peace. I have chosen physicists as one group to consider because many of them have sensed that their work might lead to the destruction of their species. I have chosen psychologists as another group, because I am a psychologist, and because I believe that psychologists have much to contribute toward achieving nuclear disarmament.

## MORAL RESPONSIBILITY AND THE ROLE OF THE CREATIVE INDIVIDUAL IN HISTORY

Any discussion of moral responsibility rests on an assumption that human beings, individually and collectively, can affect the course of history. If history is an impersonal force not under our control, there can be no effective way for people to change it, and the concept of moral responsibility is meaningless or at best a delusion. In that case my argument should come to a halt now.

B. F. Skinner (1981) has recently taken an interesting position on the role of the individual in history. He argued for recognition of "selection by consequences" as a "causal mode found only in living things, or in machines made by living things," and proposed that this idea be applied at three levels: to organic evolution, individual learning, and cultural change. At the third level he suggested a mysterious "we" who can "introduce new forms of behavior ... But having done these things we must wait for selection to occur." He concluded his argument with a remark on the role of the individual in history: "So long as we cling to the view that a person is an initiating doer, actor, or causer of behavior, we shall probably continue to neglect the conditions which must be changed if we are to solve our problems" (Skinner 1981, 504).

If Skinner is right, efficient operant conditioning would be the most favorable way of producing social change, and this would have definite implications for any discussion of giftedness. Unfortunately, our species will have little or no opportunity to experience the benefits of operant conditioning in regard to nuclear war. A different gift must be exploited: vision, or the ability to imagine possible futures without experiencing them.

A small group of gifted and creative physicists who were at the center of research leading up to the destruction of Hiroshima and Nagasaki accepted this visionary function and its role in history. To be sure, there were many brilliant physicists who did not exercise this visionary function in the moral domain, some even denying moral responsibility for the consequences of their work. My aim is neither to insist upon nor deny the occurrence or even prevalence of such cases, but to point out the existence of those physicists who did vigorously seek out moral responsibility.

Throughout the 1930s, a series of developments in physics brought the age of nuclear warfare closer. As early as 1935, Irène and Frédéric Joliot-Curie received the Nobel Prize for chemistry for their discovery of artificial radioactivity. On that occasion, Frédéric Joliot-Curie said, "scientists who can construct and demolish elements at will may also be capable of causing nuclear transformations of an explosive character" (Jungk 1958, 48).

Even earlier, in October 1933, Leo Szilard, a Hungarian physicist, had begun to sketch the features of a chain reaction. By 1935, he was frightened enough to begin to urge his colleagues toward a policy of secrecy and restraint regarding research that might lead to the use of nuclear weapons. In 1938 and 1939, further research made it clear to the Olympian few of modern physics that the making of nuclear weapons was indeed feasible. Szilard, now joined by Enrico Fermi and others, renewed efforts to persuade scientists to stop working in this direction. They failed. As it became clear that physicists everywhere would understand the potential of nuclear weapons, the same inner circle changed their goal. Now the aim was to develop the bomb before the Nazis got it. In this aim they succeeded.

Much later, Heisenberg, who stayed in Germany throughout the war, said, "In the summer of 1939 twelve people might still have been able, by coming to mutual agreement, to prevent the construction of atom bombs." Jungk, from whom I take this account, added, "He himself and Fermi, who were undoubtedly included among the twelve, ought then to have taken the initiative. But they let the opportunity go by. Their powers of political and moral imagination failed them ... They never succeeded in achieving thought and action appropriate to the future consequences of their invention" (Jungk 1958, 81).

Skinner could certainly take these events as support for his position on the futility of personal agency. If he is right, then institutional forces that are moving toward nuclear war must stumble on until they teach us their terrible lesson of consequences. But past failures of moral imagination do not mean that there is no such thing, nor that successes are impossible.

I have called this section "Moral Responsibility and the Role of the Creative Individual in History." But the affirmation of individual creativity is no denial of human solidarity and collaboration. One can believe, as I do, in individual human greatness without subscribing to the great man theory of history (Gruber 1983a). All sorts of collaboration are possible and necessary. Collaboration made the bomb. The kind of gift that will be needed if humanity is to survive must include the ability of very different people to work together. People who work for a common goal need not be similar; it is more likely that they must be different. A large and complex problem requires a variety of talents, including the skills for pooling them effectively.

There is an odd feature of the early history of nuclear fission that brings out this point. Frederick Soddy was one of the great pioneers in the study of radioactivity. In 1921 he received the Nobel Prize for work on isotopes. In 1909 he wrote a popular book, *Interpretation of Radium* (1909). The physicists and chemists of that early day already had some idea of the immense energy of the atom, and of its potential for good or evil. The prescient H. G. Wells read Soddy's book, thought about the energy in the atom, and, in 1910, wrote *The World Set Free* (1910), a short, tract-like novel about science out of control, the perfection of a nuclear chain reaction, an atomic war, and the destruction of civilization. The optimistic title comes from the aftermath. Enough of humanity survives to build a World Republic in which "the vast mass of people [expressed] a long smothered passion to make things. The world broke out into making, and at first mainly into aesthetic making" (p. 285). This was after the "catastrophe of the atomic bombs which shook men out of cities and businesses and economic relations, shook them also out of their old established habits of thought" (p. 287). After reading this book in the mid-1930s, Leo Szilard came to believe that atomic bombs could actually be built.

So Wells, the literary man, listened to the scientist Soddy. Then the scientist Szilard listened to the literary man. This coupling of scientific and literary imaginations almost worked to prevent or delay the manufacture of nuclear weapons. (I have pieced this story together from several sources: Jungk 1958; Lifton and Falk 1982; Wells 1910; West 1984).

## DOMAINS OF GIFTEDNESS

It is not necessary to decide whether moral responsibility constitutes a unitary domain of giftedness, any more than does music or physics. Perhaps the only serious treatment of the history of any domain in which personality, ability structures, intradisciplinary history, and social history are all considered together is *Born Under Saturn* by Wittkower and Wittkower (Wittkower and Wittkower 1969). Their findings led them to argue "most strongly against the existence of a timeless constitutional type of artist" (p. 293). If such is the case for the domain of art, why not expect something similar for the domain of moral responsibility? Such an approach does not diminish the importance of studying the social function and organization, media, history, and contents of any domain—and the changing psychological requirements imposed by these historical conditions. To demand that the properties of a domain be timeless and unchanging is to adopt an ahistorical Platonism that would probably destroy the whole field of social science.

To take another tack, anyone hoping to find a unitary domain with a unique and stable factor structure would expect to find certain correlations among abilities. For example, it is often pointed out that mathematicians (and mathematical physicists like Einstein) are frequently good performing musicians. But I know of no case in which a great mathematician was also a great musician. Many great composers have also been great instrumentalists—not a combination found among mathematicians who play music. This does not mean that music loses its status as a domain, rather, that the domain of music is a social-historical fact and a realm into which different people move in different ways.

Music and poetry also seem related, but there are, I think, no great musicians who are also great poets. On the other hand, at least one great visual artist, William Blake, was also a great poet. And a few great poets have also written great prose, notably John Milton. Shakespeare's sonnets alone would make him great, as of course would his plays, but he wrote no prose that we know of.

Thus, whether or not domains of giftedness are unitary, it is evident that at this level of very high achievement there are at least some cases of great work in more than one domain. But there is little reason to argue, in the cases I have cited, that creative achievement in one domain imposed the responsibility of work in another field. Matters stand a little differently in the field of moral responsibility. A case can be made for the claim that creative people in every domain could use both their eminence and their mastery of a field in the cause of human survival.

At least two Nobel prizes reflect such a dual capacity. Linus Pauling received the 1954 Nobel prize in chemistry for his work on the nature of the chemical bond and the 1962 Nobel peace prize for his part in the campaign for an atmospheric test ban treaty. Bertrand Russell received the 1950 Nobel prize, not for *Principia Mathematica*, but for his "philosophical works ..., or service to moral civilization" (Clark 1976, 512). The Nobel committee was clearly aware of Russell's long career as a pacifist.

A few years later, in 1955, Russell drafted the famous Einstein-Russell statement calling on all nations to renounce the use of nuclear weapons, a move that gave great impetus to the involvement of eminent scientists in the effort. The underlying raison d'être for the statement and for assembling Nobelists and other eminent signatories was the belief that eminence in one domain, such as in science, imposes moral responsibility on the individual that may require activity in other domains.

## MORAL RESPONSIBILITY AND PSYCHOLOGY

The psychology of morality has not always had a comfortable place in general and developmental psychology. Even William James, who thought and wrote much on the subject, gave only four pages in his 1,400-page *Principles of Psychology* (1950) to a section on "Aesthetic and Moral Principles" and concluded, "An adequate treatment of the way in which we come by our aesthetic and moral judgements would require a separate chapter, which I cannot conveniently include in this book" (James 1958, vol. 2, 675). In an important and pioneering collection of papers on developmental psychology (Barker, Kounin, and Wright 1943), the subject received scant treatment—a mention in passing in a chapter on personality development.

Piaget's seminal work, *The Moral Judgment of the Child* (1932), is the starting point for almost all modern research on moral development. But Piaget himself became generally dissatisfied with his early work (from the 1920s to the 1930s) on the egocentrism of childhood. He included in this category his work on moral judgment and referred to it very little in his later years (Gruber 1982d). In the *Festschrift* celebrating his seventieth birthday (Bresson and deMontmillon 1966), there was only one brief reference to *The Moral Judgment of the Child* and in that for his eightieth birthday, none. Important and excellent discussions and surveys of Piaget's work sometimes fail to mention this topic altogether (e.g., Boden 1980; Voyat 1982). In Geneva, in the early 1980s, there is no work in progress on moral development.

The page is by no means completely blank. James did do seminal work on the subject of moral development in *The Varieties of Religious Experience* (1958), written more than a decade after *Principles* was finished. His near contemporary (and in his time equally luminous), James Mark Baldwin, did not neglect the subject (Baldwin 1897; see also various chapters in Broughton and Freeman-Moir 1982). Piaget's work did not spring unannounced from his fertile brow, but was part of a significant Genevan tradition. He did write *Moral Judgment*, and he did open the path to Kohlberg's influential work.

My point is not that there has been total neglect of the psychology of morality but rather that this great domain of human experience has only recently begun to find its stable place in scientific psychology. There are probably three main reasons for this. First, under the severe tutelage of positivist philosophy, many social scientists strove for decades for a value-free social science. Today that impossible and undesirable dream has been almost shattered by the whole enterprise of the modern sociology of knowledge. Second, in more recent years, when the time might have been ripe for a new upsurge of interest in moral issues, the "cognitive revolution" has in many quarters prevented the study of moral issues from taking on its own special character. Indeed, both Piaget and Kohlberg themselves have mainly applied the Piagetian insights of cognitive-developmental psychology and genetic epistemology to this domain. Their finding that there are striking parallels between stage-wise development of moral judgment and stage-wise cognitive development is the main result, and it is always reported with the clear implication that cognitive development controls moral development. Third, the psychology of affectivity and the psychology of aesthetic experience are both still extremely weak. It is my guess that a mature psychology of morality cannot develop without an understanding of how values become infused with moral passion. The scientific tools to carry out that task do not yet exist.

It should be added here that important special aspects of the moral domain have occupied the attention of some psychologists over the past fifty years. During and just after the Hitler regime in Germany (1933-1945), there were some significant attempts to explain the rise of fascism, such as Fromm's *Escape From Freedom* (1941), and that Americanized empirical outcropping of the Frankfurt School, *The Authoritarian Personality* (1950). In the latter work, the authors studied a large panel of American subjects and attempted to explain how people with a certain character structure might be susceptible to authoritarian political movements. But there has been no thorough attempt to connect that work with the holocaust literature and with knowledge of moral development. Psychologists' reflections on evil are no less disjointed than their grasp of moral responsibility.

At the end of World War II, a group of distinguished psychologists published *Human Nature and Enduring Peace* (1945), including a psychologists' manifesto to the effect that war is not inevitable, not inscribed in "human nature." There has always been a steady flow of work about the psychology of aggression and war, although not large in amount compared to research such as that on discrimination learning in the rat. Throughout the 1950s, 60s, and 70s, various egalitarian movements (especially those for racial equality and women's rights) were reflected in increased psychological interest injustice morality. Now, in the 1980s, the threat of nuclear war looms ever larger, and there are renewed attempts to understand the moral issues involved in making war and making peace. It is notable that authors of important papers on this subject tend to treat nations as though they were individuals: Nations have ideals, they make assumptions about other nations, they repress unpleasant thoughts, and they believe in their own rightness.

It is certainly useful to examine the shared belief systems underlying the justification of war and strategies that may lead to war. But so far, as psychologists, we have neglected the point that social change is made by social movements, that effective movements require effective leaders and devoted participants who give their best efforts to the cause—in short, people who take responsibility. (At present, both the search for peace and the arms race are treated in the media mainly as a set of cognitive dilemmas having to do with outguessing and outgunning the other side—but not by too wide a margin, because that might provoke aggressive action.) If peace is a moral imperative for which people must struggle, then psychologists need to understand the emergence, development, and functioning of those unfortunately too few who take on extraordinary moral responsibility.

## DEVELOPMENTAL THEORY AND GIFTEDNESS

The most prominent theories of developmental stages are ill suited for explaining extraordinary moral responsibility. They are, rather, intended to explain the normal or species-typical course of development that has evolved in a relatively stable environment. Focusing attention either on species-typical or culture-wide accomplishments, they draw on the embryological metaphors of regular, highly predictable, stage-wise development within a stable environment. This may well be appropriate for understanding species-typical development. But the study of giftedness and creativity focuses not on the typical but on the atypical and innovative. Here, the metaphors of "creative evolution" (Bergson 1911) and Darwin's insistence on evolutionary divergence (Gruber 1978a) may be more appropriate.

Let us consider the general form of most stage theories. Each stage depends strictly on its predecessors. The occurrence of the later stages therefore implies the previous occurrence of the earlier ones. Thus, A C B C C C D C E C F. In such celebrated sequences as Freud's, Piaget's and Erikson's stage theories, only a single line of development is considered; they are unilinear stage theories. But the general form of argument, which might be called backward implication, can be modified to permit multilinear developmental pictures.

The geneticist-embryologist Waddington (1957) advanced the notion of *homeorrhesis*: A given developmental pathway is guaranteed by a number of constraints on development that stabilize it. In Waddington's metaphor of the "epigenetic landscape," these constraints operate much like the sides of a valley, down which a ball is rolling or a stream is flowing; minor deviations may occur, but the slopes act as a regulating mechanism, and in the main, movement follows the contour of the bottom. Waddington used this model to explain both the extremely regular course of species-typical development and the occasional major deviations that open up new "valleys" or developmental pathways. Piaget made use of the idea of *homeorrhesis*, but only to explain the regular appearance of a single developmental pathway. In effect, he postulated an epigenetic landscape with only one valley and very steep sides. To deal with a rapidly changing world in which our species can adapt and survive, psychologists need to conceptualize development as being open and capable of producing totally new adaptations to totally new conditions (see Gruber 1982c).

Evolutionary divergence lies at the heart of Darwin's theory. His discovery of the explanation of the evolutionary necessity of divergence may be as important as the theory of natural selection itself. His image of a diverging and irregularly branching pattern of development contrasts with the unilinear theories just described. To be sure, these two kinds of models do not necessarily contradict each other. One might be relevant from conception to birth or to a certain age; the other might be relevant in the time beyond. But it remains the case that in psychology this second kind of model has hardly been elaborated. Werner (1948) made a good start in that direction, but his ideas lie fallow now.

Corresponding to the contemporary theoretical emphasis on species-typical aspects of moral development, the same stress can be found in empirical studies. A survey that I have made of recent volumes of *Child Development and Developmental Psychology* (1978-1982) reveals that almost no attention is given to individual differences or exceptional cases. Even when variability data are given or when an exceptional response is mentioned, variability is treated as stemming from errors of measurement or from a flaw in the hypothesis, not as a subject with its own intrinsic worth.

In Feldman (1980), Feldman has argued that developmental theory must concern itself neither with species-typical behavior alone nor with unique, idiosyncratic behavior alone, but with both. Moreover, he has argued, developmental theory will remain weak and incomplete until it can deal with the transitions between unique and universal psychological characteristics.

Feldman's current work (1986) on child prodigies represents an important exception to this leveling or averaging treatment of developmental issues. This work focuses on exceptional children who satisfy a very high criterion level in the fields of chess, music, writing, and science. In a recent conversation Feldman has informed me that in the course of his search for prodigies in these fields he also discovered several cases of children who invite the description "morally exceptional." In one instance a child expressed his moral gifts by protecting another gifted child, who was gifted in more readily recognized domains, against the collective persecution to which children in school often subject the exceptional child.

Although developmental psychologists who are concerned with moral development have not addressed themselves to the individual case or to the exceptional person, there are various other contexts in which information is available. For example, in *Their Brothers' Keepers*, Friedman (1978) studied Christians in Nazi-occupied Europe who risked their own and their families' lives to help endangered Jews. Kren, a historian, and Rappoport, a psychologist, gave a reflective account of resistance to extermination of self and others in *The Holocaust and the Crisis of Human Behavior* (Kren and Rappoport 1980). Gaylin, a psychiatrist, described five cases in detail in his *In the Service of Their Country: War Resisters in Prison* (1970). I add to this list Goodman's (1981) study, *Death and the Creative Life*; although she did not address herself to the particular issue of moral responsibility, her panel of twenty-two creative artists and scientists reveal their concerns with issues and perspectives that stand outside themselves and their own work.

Those works deal with people's struggles against established powers that are seen as committing large-scale human devastation. These are the records of people outside the "Establishment." They are interesting and important because in the historical situation we confront—as in all situations requiring creative innovation—there must be some presumption against the established way of doing things. But an equally interesting, and in some ways perhaps more important, panel of exceptional cases comprises those individuals who succeed inside an established order and then reconsider its assumptions and their commitments. These are people with certified gifts, expertise, and eminence.

I now turn to an examination of three such cases within the profession of psychology: William James, B. F. Skinner, and Charles Osgood. As will become apparent, far from representing similar patterns or points of view, these men reveal the diverse ways in which moral responsibility may be expressed.

## WILLIAM JAMES

James's classic essay *The Moral Equivalent of War*, appeared in 1910, when he was sixty-eight years old, but its period of gestation extended over his lifetime (1995). His father was a devout and active Swedenborgian, who published thirteen books in defense of his faith. A man of inherited wealth, he was able to publish all the books at his own expense; this was also a necessity, for they did not sell. He never had to work for a living, and this may be reflected in his theological preoccupations—primarily a man's personal relation with his God, redemption, and salvation. Anderson (1980) has described a stage theory that appears in Henry James's father's theology:

> In the first step God establishes man, but in such a way that man has no connection to the divine. In this state man is utterly selfish, and it is impossible for him to attain salvation through moral action or by following ecclesiastical rules. The second step is the experience of "vastation" [something like crisis, emptying, moratorium]. Vastation is the preliminary to the third step, redemption, the process by which man gives up his selfishness and becomes unified with society and with God. (p. 85)

This movement from destructive egocentricity to constructive and redemptive sociality can be seen also in Piaget's early poem, *The Mission of the Idea* (1916), and of course, in James's *Moral Equivalent of War* (1995).

William James experienced considerable paternal pressure to become a scientist, more specifically one who would justify his father's theology with the tools of science. Eventually, he conceded far enough to study medicine, biology, and physiology at Harvard and at several places in Europe. These studies led, after some detours, to his teaching of anatomy and physiology, psychology, and philosophy at Harvard, beginning in 1873. It is James's resistance and his detours that are pertinent to the topic of this chapter.

During the years 1855 to 1860 he traveled to Europe, lived in Geneva, and studied painting both abroad and at home. He certainly could draw beautifully. All this led to a protracted double conflict. The son had trouble choosing between art and science, and he had even more trouble in communicating to his father his unwillingness to embrace Swedenborgian theology. William finally decided for science, but it is not clear to what extent he was capitulating to paternal pressure and to what extent he was choosing the field in which he felt his greater talents lay.

During the years 1867 to 1872 (age twenty-five to thirty) William suffered a profound crisis in which he could do little work, although he does seem to have studied a great deal. His difficulty was a crisis of will: how to believe in personal efficacy, how to decide that anything was worth doing, and how to do it? Then he read the French philosopher Charles Renouvier, and on April 30, 1870, recorded in his diary, "I think that yesterday was a crisis in my life." He embraced Renouvier's definition of free will: "the sustaining of a thought because I choose to when I might have other thoughts." And he exclaimed, "My first act of free will shall be to believe in free will" (cited in Perry 1964, 121).

Early in this period of darkness, in January 1868, James wrote a letter to his friend, Thomas Ward, in which he outlined two major currents of thought that were to preoccupy him for years to come: "the thought of having a will," and the idea of "belonging to a brotherhood of men" that would enable him to "contribute to the wealth of the species" through the exercise of his will (Anderson 1980, 122).

The long chapter, "Will," in *The Principles of Psychology* does not appear until chapter 26. In fact, most of it had already appeared in essays published in 1880 and 1888. The chapter covers a wide spectrum. At one extreme is the baffling question of how the movement of a finger could be construed as purposeful, and at the other extreme, the concept of personal heroism. Of the latter he wrote:

> When a dreadful object is presented, or when life as a whole turns up its dark abysses to our view, then the worthless ones among us lose their hold on the situation altogether, and either escape from its difficulties by averting their attention, or if they cannot do that, collapse into yielding masses of plaintiveness and fear ... But the heroic mind does differently. To it, too, the objects are sinister and dreadful, unwelcome, incompatible with wished-for things. But it can face them if necessary, without for that losing its hold upon the rest of life. The world thus finds in the heroic man its worthy match and mate ... He can stand this Universe ... He must be counted with henceforth; he forms a part of human destiny (James 1950, Vol. 2, 579).

From 1895 to 1904, James was especially concerned about American imperialism. He wrote ten letters to the press criticizing American colonialism in Venezuela and the Philippines. His 1904 address at the 13th Universal Peace Congress foreshadowed his 1910 essay, *The Moral Equivalent of War.* He served for a time as vice-president of the Anti-Imperialist League.

The freshness of *The Moral Equivalent of War* is preserved today. In this pacifist document James attributed great human qualities to the antagonist, the "war party." He took for granted that there are extraordinary people and energies on the other side, and that these must be enlisted if peace is to prevail. James gave a quick sketch of the history and horrors of war and summed up:

> Modern war is so expensive that we feel trade to be a better avenue to plunder; but modern man inherits all the innate pugnacity and all the love of glory of his ancestors. Showing war's irrationality and horror is of no effect upon him. The horrors make the fascination. War is the strong life ... Our ancestors have bred pugnacity into our bone and marrow, and thousands of years of peace won't breed it out of us ... At the present day, civilized opinion is a curious mental mixture. The military instincts and ideals are as strong as ever, but are confronted by reflective criticisms which sorely curb their ancient freedom. (James 1995, 312-314)

Thus, in spite of James's insistent Darwinism and biological determinism, another intellectual note was added—civilized reflection.

James sought conciliation and continued: "Pacifist though I am, I will refuse to speak of the bestial side of the war-regime ... and consider only the higher aspects of militaristic sentiment ..., intrepidity; contempt of softness, surrender of private interest, obedience to command" (pp. 316- 323). James's solutions are as follows:

> Pacifists ought to enter more deeply into the aesthetical and ethical point of view of their opponents ... this is my idea ... instead of military conscription a conscription of the whole youthful population to form for a certain number of years a part of the army enlisted against *Nature* ... Great indeed is Fear; but it is not, as our military enthusiasts believe and try to make us believe, the only stimulus known for awakening the higher ranges of men's spiritual energy. (pp. 320-328)

James's remedy (a sort of spiritual forerunner of the Peace Corps) seems inadequate today, but has it ever been tried on a wide-enough scale?

Woodward (1980) has written an excellent account of the way in which James's work on the will affected the later history of the ideas of purpose, teleology, feedback, and motivation in American psychology. But James's work was not simply a chapter in the science of a largely cognitive psychology; it grew out of his early moral concerns and fed into his later moral and social thought. The 1910 essay and its history show how a central moral concern, coupled with an idea of the morally effective person, permeated the thinking of one of the founders of modern psychology.

## B. F. SKINNER

Although I do not agree with much of Skinner's psychology, I recognize that he has been an intensely moral psychologist for many years, striving to put his scientific thinking to social use. *Walden II* (1948) was an immensely popular book and led to the establishment of an intentional community with the same name. I have already referred to his use of a mysterious "we" standing above individuals. Similarly, in *Walden II*, Skinner resorted to a directing personality who stood outside the system of positive reinforcement. *Beyond Freedom and Dignity* (1971) also received great critical attention, much of it negative.

It is of some interest in connection with the theme of this chapter that Skinner (1938) decried both the theoretical place and the practical use given to the idea of negative reinforcement. Surely Skinner or one of his disciples would view the rapidly developing failure of the MAD strategy (Mutually Assured Destruction) of nuclear deterrence as an unhappy vindication of his critique of punishment.

In his autobiography (1967) Skinner stated that he read Bertrand Russell's *Philosophy* (1927) while floundering in his "Dark Year," just after graduating from college. It was Russell's clear and enthusiastic account that led Skinner to J. B. Watson and started him toward his lifelong career as a behaviorist. A little later the same year, he read an article in the New York Times Magazine in which Pavlov was praised to the skies. This tipped the balance, moving him away from his unpromising start as a writer and toward graduate work in psychology. (Skinner's youthful efforts as a writer have recently been described by Coleman (1984), whose account I read after writing this chapter. The picture Coleman gives is consonant with what I have written.)

Little social conscience or public morality is evident in Skinner's younger years. In his autobiography there are long accounts of various practical jokes, odd jobs, and his adolescent sexual worries. He characterized his college years as "intellectual vandalism"—probably a little overdrawn. Those were years of prosperity and self-satisfaction for middle-class America, and Skinner was a member of an upwardly mobile family. His social concerns came later. From his own account, *Walden II* did not come out of any long-abiding prior commitment. At a dinner party in 1945 (when he was forty-one years old) he had a conversation about what could come after the war, which led to the idea for the book. Then, in 1948, "to my surprise, I began to write Walden II" (Skinner 1967). In 1977 Skinner summed up his position on the controversy generated by that book:

> Walden II was an early essay in the design of a culture. It was fiction, but I described a supporting science and technology in *Science and Human Behavior* (1953) ... I returned to the issue in *Beyond Freedom and Dignity* in 1971. Unfortunately, that title led many people to believe that I was opposed to freedom and dignity. I did, indeed, argue that people are not in any scientific sense free or responsible for their achievements, but I was concerned with identifying and promoting the conditions under which they feel free and worthy ... There is a further goal: what lies beyond freedom and dignity is the survival of the species, and the issues I first discussed in Walden II have become much more pressing as the threat of a catastrophic future becomes clearer. Unfortunately, we move only slowly toward effective action. (pp. 380-381)

Skinner is an interesting case because he came late to his expressions of social concern and because, as the embodiment of tough-minded empiricism in psychological science, he still found time to write his utopian novel and other reflections on large human problems. Until they know much more about it psychologists should expect surprises in their studies of the development of moral responsibility.

## CHARLES E. OSGOOD

On June 10, 1963, President John F. Kennedy announced a "Strategy for Peace." He found something to praise the Russians for and declared that the United States was stopping all atmospheric tests of nuclear weapons, and would not resume them unless another country did so first. On June 15th, Soviet Premier Kruschev announced that the Soviet Union was stopping the production of strategic bombers. On August 8th, the United States, Great Britain, and the Soviet Union signed a partial test ban treaty (agreeing not to test nuclear weapons in the atmosphere, in outer space, or under water). A thaw in the cold war seemed under way. The sociologist Amitai Etzioni called this "The Kennedy Experiment" (Etzioni 1976; see also Osgood 1980). In his *Autobiography*, Osgood, after recounting these facts, remarked, "But then, on November 22, 1963, the Kennedy Experiment came to an abrupt end in Dallas, Texas" (Osgood 1980).

The story has a place in Osgood's *Autobiography* because in 1962 he had published his book, *An Alternative to War or Surrender* (1962), in which he had proposed the strategy of Graduated and Reciprocated Initiatives in Tension Reduction (GRIT). It was a fitting idea for a cognitive behaviorist like Osgood to propose negotiation through actions rather than through the long and often dismal process of negotiation through words. What Osgood proposed was the strategy of announcing and carrying out a small but clear-cut act in the direction of disarmament or tension reduction and waiting for the other side to react. This process, he argued, could lead to a general winding down of the arms race.

Osgood had sent his book to Kennedy in 1962, together with other papers on the same subject. No one, including Osgood, would suggest that a single source of influence could determine the complex decisions at stake. But a clearly reasoned argument in favor of a particular strategy may help a group that is considering a move in the same direction to clarify its thinking. After all, strategies do arise out of thought and argument.

Osgood did not become involved in efforts toward arms control and disarmament through a direct path. In 1958, Osgood was 42 years old, already a very distinguished psychologist. He had published his massive and influential *Method and Theory in Experimental Psychology* in 1953 and *The Measurement of Meaning* in 1957. In 1958, he spent a fellowship year at the Center for Advanced Study in the Behavioral Sciences at Stanford University. His plan was to write a book to be called *Method and Theory in Psycholinguistics*. That book never got written. Osgood's office at the Center lay between that of the cognitive psychologist, George Miller, and that of the psychiatrist, Jerome Frank. The latter had already begun to bring his professional expertise and other gifts to bear on the problems of war and peace. He and Osgood joined forces at the Center in organizing seminars on the threat to survival of the human species in the nuclear age. This work led eventually to Osgood's book on GRIT.

There is nothing much in Osgood's early life to suggest that his work would take this direction. His boyhood certainly fits the description of that of any gifted youngster. He read science fiction and had a wide-ranging interest in jazz (he still plays a mean piano). Giving up early aspirations to be a novelist-journalist, he committed himself to becoming a scientific psychologist. After studies at Dartmouth and Yale, he did a stint in the Air Force, where his main duties were research for the improvement of gunnery training. After that he had an almost meteoric career at Yale University and the Universities of Connecticut and Illinois, the latter at which he has remained for many years. He began publishing psychological articles as an undergraduate and has worked steadily in psycholinguistics, social psychology, and some branches of experimental psychology.

In his *Autobiography*, he describes his work under three themes:

Theme I—"Meaning in Individuals"—is essentially an attempt to apply a liberalized, cognitivized Hullian behavior theory to the problem of the meaning of words. Theme II—"Meaning Across Cultures"—is a massive, international attempt to elaborate the idea of a multidimensional semantic space that could account for all meaning in all languages. Theme III—"Meaning for Human Survival"—is the effort for world peace described above (Osgood 1980).

Theme I dominated his efforts in the 1950s, and Theme II in the 1960s. Theme III did not appear actively until 1958 and has been very important but intermittent ever since. Osgood's personal ambivalence about making a full commitment to Theme III is shown in two parts of his *Autobiography*. In 1963, when he was preparing his presidential address to the *American Psychological Association*, he knew that everyone expected him to make a speech about international affairs. After much hesitation he spoke "On Understanding and Creating Sentences," restricting himself to pressing issues in psycholinguistics (cited in Osgood, 1980).

Somewhat ruefully and a little puzzled about himself, Osgood ended his *Autobiography* with a confession:

> One might think that, as my estimated probabilities for the survival of Mankind in the nuclear age go down (as they have been doing over the past few years), my urge to give highest priority to writing *Mankind 2000?* should go up. But just the reverse has been the case. As prospects for Mankind's survival go down, the more I feel driven—like an artist getting ready to "paint his last picture"—to write my last scientific contribution, *Toward an Abstract Performance Grammar*, regardless of whether anyone will be around to read it. It is as if I, too, am subject to a selfish egoism that, under stress, takes precedence over altruism. (Osgood 1980, 387)

Osgood, in spite of his conflicts has not done at all badly, has he? He has given much of his time and energy, proposed an original idea for tension reduction, and found many platforms from which to expound it. He has used his mind and his eminence well. From the whole tone of his *Autobiography* it is clear that he thinks of himself as an effective human being, and he thinks that individuals can have some effect on the course of history. And yet, when faced with this most urgent question of all, like most of us, he has held his energy in check and has worried about that, too.

## "OUGHT" IMPLIES "CAN" IMPLIES "CREATE"

Any "ought" statement necessarily implies "can": It makes no sense to say that something ought to be done unless it can be done. But how do we know what can be done? In the realm of difficult, intractable problems, such as the threat to species survival, only protracted, vigorous, and creative work can be expected to reveal the full range of the possible. Creative work almost always takes a long time (Gruber, 1981k; Westfall 1980b).

If Piaget and Inhelder's (1958) description of adolescent intellectual development is even approximately right, that is the time of life when the real becomes a special case of the possible. At least for some, it is no longer necessary to be a prisoner of either the past or the present. But this surge in capacity for abstract and visionary thought is not instantly translated into effective creative work. Nor does a fruitful and impassioned integration of moral responsibility and creativity necessarily follow.

Psychologists have not produced a very clear picture of the course of moral responsibility as it becomes interwoven with other features of the creative person's career. Lehman (1953) studied the age of creative achievement in many fields of endeavor. In general, he found that both first and major achievements in mathematics and in the natural sciences come rather early in life, somewhat later in the life sciences, and even later in literature.

Lehman's results suggest that achievement in the ethical realm comes, not very late, but somewhat later than in other fields. The picture is actually quite variable. James's concern with moral responsibility was lifelong, but his public productive achievements in this realm came rather late; Osgood and Skinner made their ethical concerns public in their forties. Piaget's early passionate involvement with moral issues, as a public scientific concern, seems to have diminished or gone underground by about his fortieth year (Gruber 1982d).

A striking phenomenon has recently appeared in American life, a special sort of retirement syndrome typified by men like Rickover, MacNamara, and Colby. Once out of the military institutions in which they enjoyed eminence and power, they come to the fore with deep misgivings about the chance of avoiding catastrophic nuclear war. Thus, although the visionary function, and the distinction between the real and the possible, may become pronounced in adolescence, their expression in the moral domain displays an extremely variable pattern.

### *Different Ways of Thinking About Peace*

Future research on morality, giftedness, and creativity must deepen understanding of the different ways of thinking and acting about the moral imperative of peace. It would be helpful to approach this task in as detached a spirit as possible, bearing in mind that there is not one right way. Let us compare three different ways of thinking about the threat to human survival. Each of them might have positive or negative consequences, depending on how it is employed.

*Worst Case Thinking*. One approach to moral issues is to dwell on extreme cases and their consequences, such as the firestorms produced by a nuclear war, the "nuclear winter" recently brought to public attention by Sagan and others (Ehrlich 1984; Sagan 1983a; Turco et al. 1983), or the consequences of a limited nuclear war under a particularly unfavorable confluence of other circumstances. When Herman Kahn wrote *On Thermonuclear War* (1961) and introduced the phrase, "thinking the unthinkable," his intention was to increase the credibility of the United States' nuclear deterrent: He was endorsing and justifying the MAD (Mutually Assured Destruction) strategy. In contrast, when men like George Kennan (former U.S. Ambassador to the Soviet Union) or Nick Humphrey (British ethologist who made a celebrated appearance on BBC-TV) confess their enormous pain and difficulty in imagining the consequences of nuclear war, they are thinking about the unthinkable. They are not contemplating waging nuclear war or pretending to be prepared to wage it—they are opposing it and opposing the MAD strategy that might engender it.

*Utopian Thinking*. A second way of thinking about moral issues is to imagine some ideal end state and try to construct imaginatively what it might be like in all its detail, without much concern about how to reach the goal. Utopias are ways of making basic allegiances and premises clear, so that one person's Utopia is always another's prison. Even the idea of a world without war has its detractors. William James, too, thought that the institution of war did in fact evoke some of humankind's noblest qualities. Rather than sacrifice these, in *The Moral Equivalent of War* he proposed a Utopian arrangement that would let us eat our cake of peace and have our savage splendor. Boulding (1982) has argued that many people find it hard to work for peace because they have lost hope; they can no longer imagine a peaceful world. She has invented the ingenious device of workshops in which the participants are asked to imagine momentarily a world without armaments, then to imagine what the immediately preceding state of affairs would be like, and so on back to the present.

*Systems Thinking*. In his book, *The New Utopians*, Boguslaw (1965) argued that some social systems thinking is a modern form of utopianism. The particular form that I have in mind here is intended to be a contrast to the previously mentioned heuristics. Instead of imagining a drastic change in the world, one imagines a set of minimal changes that may accomplish a large and important result, but without upsetting anyone's apple cart. Some combination of improved hot line, cautious application of Osgood's GRIT idea, and mutually agreed peaceful surveillance (MAPS) might represent an application of this strategy. But it must be remembered that MAD is also put forth as an application of global systems thinking or, if not global, at least joined in by the two superpowers.

Each of these heuristics has the following characteristics. It is a general strategy that can be applied in more than one way and with varying outcomes. It delineates a form of idealization or limiting case. The thinker has the option of restricting her- or himself to dwelling in the limiting case, or of using it as a point of departure for further, possibly more realistic, thought.

In applying this line of thinking to the present concern with giftedness and creativity, one key point leaps into view. There is no reason to think that the same people will be good at or be invested in all three approaches. True, it is believed (on rather slender evidence) that a great abstract artist will also be a good, but not necessarily great, realistic painter. Picasso's early representative art is striking because it is Picasso's—but we do not laud him as though he were another Rembrandt.

If this line of thought has merit, it leads to the conclusion that there is no single turn of mind that can be labeled "moral giftedness," but rather a number of different ways of thinking, all of which could be useful if harnessed to the common goal. Then the gift needed is the human solidarity to mobilize the gifts we all have for that great moral purpose, the survival of our species.

# CHAPTER 7

# Creativity in the Moral Domain

*The original initiative not only for my work, but for that of many other people in the fields of moral creativity, political action and, recently, citizenship, has come from Howard Gruber. In 1983 Howard organized a seminal conference at Yale University, asking the question: "What is extraordinary moral responsibility?" Subsequently, this question was asked within the context of the Social Science Research Council Committee on Learning, Development and Giftedness, and a further workshop was held in New York in 1985. Howard's initiative in setting up these workshops, and more importantly his own vision, have had the effect of enabling many people to bridge the gap between moral and political psychology, to ask crucial questions about how political action may have a moral dimension. These questions now increasingly inform sessions of the International Society for Political Psychology, and of MOSAIC, the Moral and Social Action Interdisciplinary Colloquium, a cross-national, cross-disciplinary network of scholars interested in moral—in the broadest sense—issues.*
Helen Haste, Ph.D.
Professor of Social Psychology, University of Bath

The moral dimension has always been inseparable from any real understanding of a purposeful life. Thus, when the substitute lecturer in my first psychology class turned out to be Solomon Asch, I was mesmerized from the moment he began to speak.

Asch came into the room, sat down at the desk, looked out of the window and then spent the whole hour telling us about experiments in social psychology by Lewin and his followers. These experiments were published under such juicy titles as *An Experimental Study of the Effects of Democratic and Authoritarian Group Atmospheres* (Lippitt, 1940) and *Patterns of Aggressive Behavior in Experimentally Created "Social Climates"* (Lewin et al. 1939). But to my sixteen-year old, socially-engaged heart and mind this meant you could study war and fascism in the laboratory – and, by the same token, peace making and democracy. This encounter took place in 1939, as the Nazis were bringing their witch's brew to a boil. Nothing could have appealed more strongly to me than the lesson Asch taught that day. And this was doing science! How wonderful!

I never did pursue the line of Lewin's experiments. In my own empirical research, I took up another one of Asch's preoccupations: his defense of the integrity of human truth-seeking efforts.

More important, perhaps, was the theoretical grounding of these efforts in Lewin's version of Gestalt theory. Lewin rejected mere statistical generalities, which he excoriated as stemming from an "Aristotelian" mode of thought. Instead, he insisted on "Galileian" thinking and the imperative of finding ways of understanding the total situation, i.e., all the forces acting on the person in a given situation at a given time. Two of Lewin's papers that grew in importance for me over the years were *The conflict between Aristotelian and Galileian modes of thought in contemporary psychology* (Lewin 1931) and *Behavior and development as a function of the total situation* (Lewin, 1946). As I look back on my work on creativity and my use of the case-study method, I owe a great intellectual debt to Lewin and the other Gestaltists, especially Asch.

Although the term does not crop up in Lewin's writing, it might well be said that almost all of his work bears on issues pertinent to creativity. He emphasized purposefulness, freedom, and the need to conceptualize the actual psychological situation of the whole person. All of these guidelines provide necessary pathways for understanding the creative person at work, and every one of them has an important moral dimension. In this light, moral issues become political, and vice versa. Social questions—whenever societal questions arise, which is to say almost always—cannot be considered in some neutral, value-free way.

When I introduced the term *extraordinary moral responsibility*, I had three main goals in mind. First, to demonstrate how the varieties of moral thought and conduct grow as history unfolds and our concepts of history and culture are amplified. Second, I wanted to understand how reflections on moral judgment are transformed by moral conduct—goals evolve in the course of pursuing them. Each individual is the nexus of many schemes, each with its own history. Third, I wanted to examine extraordinary moral responsibility as a form of creative endeavor, one which well illustrates the way in which creative people at work construct what I term a *deviation amplifying system*. In cases of extraordinary moral responsibility, a person acts at—and goes beyond—the limits of what can be done about something that many people deplore but mostly feel powerless to change.

In today's money-worshipping culture it is widely believed and triumphantly announced that the path to economic health, and consequently societal well-being runs through vigorous, even untrammeled and uncritical accumulation of private and corporate wealth, and free operation of the market. Coupled with these economic policies and justifying them, is a system of beliefs about the psychology of motivation that merits psychological scrutiny. The central idea remains Adam Smith's conception of the free market, governed by the profit motive as the natural force entailed in making money and getting rich. What may be new in this system is the belief that every one wants to get rich, should and could do so if only the free market and profit motive were left to their own devices. This orientation affects every aspect of modern life: education, conservation, medicine, penology, technology, the military, and so on without end. All of these ideas are as much psychological as they are economic and political. Undertaking a constructive, and critical scrutiny of society as a whole might be the most valuable thing that social scientists could do in the century now beginning.

As things stand now, at the beginning of the twenty-first century, it is about equally easy to compile a list of hopeful things as of hopeless ones. But such lists tend to conceal the differences in magnitude between the two orientations. Of course, it is wonderful to save a few hundred acres from the woodsman's axe but meanwhile the gigantic bulldozers are gobbling up thousands of acres of rainforest. Of course, it is wonderful to save some particular species from total obliteration, but meanwhile hundreds of species become extinct every day. Of course, progress is being made in birth control, very real progress, nevertheless the human burden on the earth's capacity will double by the year 2030. And so the litany of despair continues. It becomes necessary to utter the taboo idea: We are losing—it may be too late to turn the tide.

Or, perhaps a change in planetary morality is a multi-stage process, with one of the early stages being the discipline of despair. Gallows humor may have something to teach us. Can we collectively learn fast enough?

# Creativity in the Moral Domain

## *Ought Implies Can Implies Create*

The combination *Creativity in the moral domain* seems portentous and promising. In a world laboring under multiple crises, often with a pressing moral aspect—such as eating well while millions starve—why not harness our most creative powers for the betterment of all? And on the other side, in a world blessed with many creative people with all sorts of special abilities, why not ask whether some of that creative power can and should be turned toward improving the chances of planetary survival under happier conditions?

But for some thinkers the juxtaposition of the terms *creativity* and *morality* seems odd. In exploratory discussions of the idea, the remark "oxymoronic" occurred more than once. This suggestion that these ideas are contradictory presupposes a stable, well-ordered society. In such a world, for example, if we were training bank employees in moral judgment (Oser & Schlaefli, 1985), we might want them to be scrupulous in observing conventional morality, but not too creative! More generally put, one of the major functions of a moral code is to stabilize social interactions by conserving certain agreed upon values. All this to protect whatever a given community means by the *good life*.

The present array of articles on creativity in the moral domain is borne of other considerations. The writers for this issue have responded to our suggestion that they "range from private morality to matters of public and planetary concern," and they write with a moral passion that is justified by the state of the world.

In this introductory essay I deal at some length with the issues of moral diversity and the problem of moral relativism in their relation to the subject of creativity in the moral domain, especially in a time of global crisis. I briefly treat the relation between moral thought and creative moral conduct, but this subject is the focus of several essays in this collection. Also, although I do not touch here on the moral responsibilities of creators in other domains, such as art and science, this subject is dealt with in several other articles in this volume, and I have written about it elsewhere (Gruber 1989b).

Recent writing on creativity, including my own, has taken a cognitive turn, linking it up with various aspects of the burgeoning cognitive sciences. While this cognitive approach has many virtues, it can never succeed in explaining creativity and its development unless it is coupled with a fresh and vigorous examination of the relation of creative thought to the affects, values, and intentions of the creators. Although

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this task applies to creativity in all domains, how knowledge, purpose, and affect combine to make for creative action becomes an especially pressing problem when we turn our attention to creativity in the moral domain.

## CRISIS, MORALITY, AND CREATIVITY

We live in a time of rapid social and economic change, and widespread feelings of malaise. The population of the world has more than tripled in this century and will more than double again by the middle of the next century. All sorts of natural resources necessary for the good life are threatened with exhaustion or pollution, rendering them useless or worse.

Implicit in any moral code is a set of values and priorities. New historical circumstances demand a rethinking of these matters. Conventional morality is not enough. New answers are needed, even new questions. Ergo, we need creativity in the moral domain.

The ethos of invention, adventure, and expansion is perpetually attractive. It is written into our creation myths. But now its consequences force us to reexamine our moral imperatives. For example, in considering the European colonization of the New World, who—except for a handful of Native Americans—has not gloried at the brave spectacle of small sailing ships crossing the Atlantic and ox-drawn wagons crossing the American prairies and plains to escape population pressures, state-ordained religions, and economic and political problems of the Old World? In a poem written not long after the American revolution William Blake expressed such feelings:

> Tho' born on the cheating banks of Thames
> Tho' his waters bathed my infant limbs,
> The Ohio shall wash his stains from me:
> I was born a slave, but I go to be free.

Unhappily Blake's dream is no longer attainable: The frontier has disappeared and population growth spells impending disaster for uncounted millions. The opening up, somewhere, of a new gigantic oil field carries with it the promise of an uninterrupted energy supply for one or two generations of automobilists and other users ... followed by asphyxiation of the planet for those who follow.

The doubling period of the world population is now about forty years, which corresponds to a growth rate of only two percent per year. Enthusiastic entrepreneurs might be elated at the prospect of such an increase in the market for their wares, but others might be troubled by the notion that an insidiously slow growth rate can produce such dramatic effects. Consider this parable, questioning the ethos of more and faster growth. Try to imagine,

> a pond weed that doubles each day the amount of pond surface covered and is projected to cover the entire pond in thirty days. The question is, how much of the pond will be covered in twenty-nine days? The answer, of course (but not

> so easy to find), is that just half of the pond will be covered in 29 days. The weed will then double once more and cover the entire pond the next day ... Exponential growth contains the potential for big surprises. (Ehrlich and Ehrlich 1991, 15)

If we take generations as our units of time we may well be at about the twenty-eighth day. It comes as a shock to realize that economic decisions we make today—especially the iron law that prosperity requires continued economic growth and consumption—may well mean misery for our grandchildren. Is this not a moral dilemma of the greatest magnitude?

## OUGHT, CAN, AND CREATE

If moral decisions are conditioned by the circumstances in which they are made, then the temporal horizon of our moral thought must be considered. Instead of expanding toward the eternity promised to those who live a life of goodness, our moral horizon in the real world seems to be rapidly shrinking.

Thinking once more of our pond of weeds, do the moral priorities we set for the first day apply to the 28th day? (see also Gruber 1992d). If our situation is near-critical, will it suffice to reorder our priorities, or must we invent wholly new ways of looking at and dealing with our problems? That is the question that motivates our examination of creativity in the moral domain.

In a stable and well-ordered world a simple logical relationship applies:

OUGHT implies CAN implies ACT.

In other words, whenever we assert that something "ought" to be the case, we presuppose that it is possible, that it can be done. Furthermore, once we know that something ought and can be done, action is called for.

Unfortunately, in an unstable, disorderly world, teeming with intractable problems and looming crises, we are confronted with problems for which no preconceived solutions exist, and with the need to invent new ways of framing our moral problems. When we are faced with tasks that are both difficult and new, even expertise is not enough. Creative work becomes indispensable. In such a world:

OUGHT implies CAN implies CREATE.

In other words, Ought implies Can, but we have no way of knowing what can be done without striving creatively to discover all the nooks and crannies and the limits of the possible. If this creative effort is successful, the reach of Can is transformed and action on behalf of Ought again becomes possible.

It should be noted here that Kohlberg's essay (1971), the title of which begins with the phrase, "From Is to Ought," makes a different distinction from the one I have in mind when I speak of Ought and Can. For him, "Is" refers to psychological facts about moral reasoning while "Ought" refers to philosophical concepts bearing on the same moral issues. The burden of Kohlberg's essay is that there must be and is a parallel between these two epistemological categories. In the present discussion, however, Ought and Can are both intended to be psychological categories.

In his classic, *The Psychology of Interpersonal Relations*, Heider (1958) examined the first step (Ought implies Can) and clarified it beautifully. But I do not think he took the second step (Can implies Create). And it is this second step that becomes poignantly pertinent in times of crisis. Likewise, the English analytic philosopher, Austin (1961/1956), in his essay "Ifs and Cans" treated many of the nuances of "can," and its preconditioning "ifs" but nowhere asked how each "can" arises out of human effort.

The formula, OUGHT implies CAN implies CREATE, is only an approximation, for at least two reasons. First, the two occurrences of the word "implies" have different meanings. They do not have the same demand character. In "OUGHT implies CAN" we are speaking of a logical necessity: It simply does not make sense to say that we ought to do something unless it is possible. In "CAN implies CREATE" the "implies" has only the force of a suggestion.

Second, it is not so much CAN that drives CREATE as CANNOT. If (and only if) something ought to be done and we do not see how to do it, then, to satisfy the demand of Ought, we need to become creative.

A claim that this need-to-become-creative in the moral domain must be construed as a moral imperative might go a little too far. To be realistic, this claim would depend on the presuppositions that everyone can be creative and that creators can voluntarily turn their creative powers in new directions, as needed. Because these are not settled questions, for the present I claim only that the second "implies" has the force of a suggestion.

Toward the end of his life Piaget produced a two-volume monograph, one on the evolution of the child's idea of possibility, and the other on the evolution of the child's idea of necessity (Piaget 1987). But in this work he did not apply his thinking to the moral domain.

The mutual interactions among Ought, Can, and Create should be noted: What we believe to be possible shapes our sense of what must be done. As a creator immerses him- or herself in a task, the work generates a kind of personal imperative. Indeed, the imperative mood of Ought cannot be effective in the real world unless the impersonal Ought is transformed so that it becomes guide and a goad to specific people who take responsibility for what needs doing. How "It needs" and "I can" give birth to "I must" remains enigmatic (Gruber, 1981e).

We can come at the relation between creativity and morality from another angle. In his article in this issue, Runco (1993) argued that creative ability and moral reasoning are unrelated variables. In the studies of Italian youth, Andreani and Pagnin (1993) made a similar point: Tests of creativity do not correlate significantly with tests of level of moral reasoning.

We should be careful, however, not to interpret this orthogonal relationship as meaning that these characteristics have nothing to do with each other. All it means is that *variations* in one characteristic are not correlated with *variations* in the other. Any given individual—or social group—must still work out a coherent and adaptive way of using all of his or her or their capabilities correlated or not. To take a simple example of this surprisingly elusive point, consider the correlation between interest in music and nearsightedness. It is probably close to zero. But a myopic would-be musician must still obtain spectacles in order to read scores. Moreover, if different individuals have different abilities, their activities must be coordinated in a harmonious way, or the community will wither. Person by person and group by group, appropriate relations must be constructed between the inventive and cognitive capacities available and the evolving moral code. Two kinds of reason have been given for maintaining a sharp separation between morality and creativity. On the one hand it is claimed that morality is essentially a historically evolved, culturally determined code; in that case creativity seems to be entirely excluded from morality, and moral conduct consists in conforming to the code. If conflicts or dilemmas arise within that frame, each society must have a mechanism for resolving them. Even here some limited creativity, not challenging existing mores, is possible. Klineberg (1940) described an Eskimo society's handling of a case of divorce and jealousy between two men: they "duel" in poetry. Each man composes a poem, which he figuratively hurls at the other, the whole village in attendance. The winner is the man judged to have produced the best poem.

At another pole lies the claim that morality and creativity are unrelated because morality is best expressed in the developmental movement through a universal series of stages. In this vein, for example, Turiel (1983) distinguished between morality and convention: Conventions vary from group to group and from society to society; but moral development is universal and everywhere exhibits the same sequence of stages. It follows therefore, that if (as is widely agreed) creativity is by definition innovative and idiosyncratic, the more it succeeds in breaking with its evolutionary and historical past, the more it brings into question the stage theorist's criterion of universality. I have developed a similar theme in a chapter *On the Hypothesized Relation between Giftedness and Creativity* (1982c) where I argued that precocity in following a conventional, recognized developmental path is not necessarily a good recipe for later creativity.

It should be emphasized that both of these approaches—the conventionalist and the universalist separation of morality and creativity—rely on a certain methodology focusing on the evaluation of claims that *differences* in one domain, morality, are correlated with *differences* in another domain, conventionality. Whatever the rather modest evidence for such claims may be, there is another side to the story, which is the heart of my argument: The creative person (whether this be Everyperson or someone specially favored by the gods) must compose or construct some relation between his or her moral thought and feeling on the one hand and his or her creative impulses on the other. In times of crisis this need is enhanced and some creators come forward with solutions that integrate past, present, and future needs.

I cannot stress too much the methodological point, that in an organismic constructivist perspective what is important is not the linear correlation of variable with variable, but the aptness of the fit between part and part composing the whole; bearing in mind, also, that the particularity of this aptness changes as the organism develops. To take only one example: During one period of the individual's life the umbilical cord must be strong and well-attached; later it must be cut, and it must wither and disappear.

The very fact that knowledge and technology on the one hand and moral feeling and thought on the other are all historically conditioned almost guarantees that their relationships will be uneven, at most moderately correlated. The contemporary struggle over abortion rights is a case in point. The progress of technology has made abortion easier and easier, safer and safer. Meanwhile, the political struggle over abortion rights has grown in ferocity. On the one hand, a relatively steady movement in one direction; on the other hand, a wavering controversy. To make matters more complicated, more historically determined, these relationships vary from country to country.

## HOW MANY MORALITIES?

By far the preponderance of research on moral judgment has followed lines laid down by Piaget (1932) and pursued so persistently by Kohlberg (1984). Recently, especially in the work of Gilligan (1982), critical thought and empirical work have brought to light the point that the dominant Kohlbergian approach is concerned with a justice morality; Gilligan has brought out another kind, a morality of caring.

Further scrutiny suggests that there are other moralities, each of which has, in one context or another, some claim to being just as fundamental as justice and caring. Campbell (1990) pointed out that inherent in Asch's social psychology (1952) is a persistent concern for a morality of truth. Campbell spelled out, simplified, and compressed matters that were treated more discursively in Asch's own writing. In *Asch's Moral Epistemology for Socially Shared Knowledge* (the title of Campbell's essay) there are three imperatives:

> Trust: It is our duty to respect the reports of others and be willing to base our beliefs and actions on them.
> Honesty: It is our duty to report what we perceive honestly, so that others may use our observations in corning to valid beliefs.
> Self-respect: It is our duty to respect our own perceptions and beliefs, seeking to integrate them with the reports of others without deprecating them or ourselves. (Campbell 1990, 39)

If these conditions are not satisfied, knowledge cannot be effectively shared and social existence will not be possible. Hence they are moral imperatives. Ergo, there is a morality of truth.

Asch did not flinch from the idea of human nature—that there are some necessary and universal features of human experience and conduct. In this instance, and throughout his work there was, in his words, "a theme central to my thought: that there is an inescapable moral dimension to human existence" (Asch 1990, 53). Societies may differ widely in their attitudes toward truth. For example: Do they punish liars, and if so how? Do they characteristically search out disagreements and contradictions? What are their standards of evidence and argument? But despite these differences, without some irreducible standard of truth-telling, the cooperation necessary for social life must fail.

In a recent article Hammond, Harvey, and Hastie (1992) called for "separating truth from justice." Their point, of course, is not to oppose one against the other but to permit their more effective articulation. Although his approach was entirely different, Köhler's goal was similar, in his classic, *The Place of Value in a World of Facts* (1938).

There are yet other moralities that seem equally fundamental in our civilization. A short list would include:

Justice Morality (Kohlberg, Piaget);
Caring Morality (Gilligan);
Truth Morality (Asch);
Freedom Morality (Fromm 1941);
The Work Ethic (Veblen 1914);
Planetary Morality (Ehrlich and Ehrlich 1991);
Religious Morality.

Colby and Damon (1992) gave a similar list, but they do not mention the work ethic or planetary morality. Of course there are other moralities that come to mind. For most of us, life itself is the fundamental value from which all the others spring—if not our own lives, the life of some larger community, or just life in general. I believe that life morality could be dealt with as the superordinate combination of caring and planetary morality. I seem to remember that when I was a child I read a piece by Tolstoi entitled, *Cleanliness Is Next to Godliness*, which would add one more item to the list. Religious morality is certainly no one thing, since there are many religions and they each make different fundamental moral demands.

We need some way of dealing with this variety. One path would be the path of conceptual analysis and reduction, demonstrating that some one value is most fundamental and that all the others derive from it. This idea lies behind the enormous research efforts that have been expended on showing that justice morality follows a universal, unilinear developmental course in which stage follows stage in an orderly progression. If that were the case, opportunities for creative solutions to moral problems would be severely limited, for creative lives follow neither linear nor universal paths—they follow the road less traveled. Fortunately, there are other paths—more open, more complex, and inviting creative exploration.

## COPING WITH MORAL DIVERSITY

I want to suggest such a path, one that accepts the variety and tries to cope with it. There are three key points:

1. For each entity to be considered—a whole culture, a nation or other community, a family, or an individual—we can draw up a profile of the particular values prevalent in that entity, including some representation of their relative importance for the participants.
2. We need an approach to representing the relations among these moral values: how the participants move about in this moral space.
3. We need some way of reflecting on, and as I believe, avoiding the extreme relativism that might seem to be favored by the notion of moral diversity.

This approach does not eliminate all reduction to relationships of hierarchical structure. The point, however, is to find the actual relationships thought out and experienced by real people, rather than impersonal philosophical abstractions. We may find that, without any change in the list of fundamental values, important innovations can be created by a change in their relationships. I believe that this was the case in Gandhi's life as depicted in Gardner's (1993b) article in this issue.

To take a more limited example of moving about in a moral space, recently someone close to me had an insight that was important for him. He earns his living and assuages his soul through his work as an environmentalist. The work of *Amnesty International* was brought to his attention. At first, he brushed it aside as irrelevant to his planetary concerns. Then it struck him that in a dictatorial political atmosphere it might be impossible to tell the truths necessary for preserving the environment. Thus, he constructed a kind of ring-structure linking his planetary morality with the moralities of truth and freedom. Similarly, in this collection Benchoam (1993) relates the story of her survival in prison and her later development in a way that links the moralities of freedom and caring. The powerful image she and a fellow prisoner created—the map of Latin America in the shape of a suffering woman—comes close to the idea of planetary morality.

In this collection Goswami's approach (1993) to the issue of freedom is quite different from those mentioned above. He is concerned to show that the world is not constituted of completely deterministic relationships; therefore, metaphysically, some free choice is possible. Without such freedom, creativity would be out of the question. Thus, unlike Fromm (1941), for whom freedom was a value in its own right, Goswami treats freedom as a means to a higher end, the possibility of leading a moral life.

I think I have said enough to indicate how differences in moral perspectives may sometimes be the result of the items included in the moral code, and sometimes the result of the different ways in which various elements of a moral code can be organized.

## CREATIVITY AND THE PROBLEM OF MORAL RELATIVISM

The subject of creativity in the moral domain raises all the general questions that arise in any study of creativity, and then some more. How can we judge if a work, or an act, is really novel? How can we judge if it is really good? (For a more extensive discussion of the concept of creativity see Wallace and Gruber 1989.) In the arts, the issue of judgment and consensus is not usually a life and death matter: Pictures of varying quality can hang in the same museum, and different viewers can have their own preferences. In the sciences, truth morality is preeminent (but not exclusive): An elaborate set of mechanisms has evolved for testing the validity of scientific results and although the system is far from infallible, a substantial degree of warranted consensus is usually possible (Giere 1988).

In the moral domain, however, the problem of consensus is much sharper. Matters of grave human import, often life and death questions, do hang in the balance, yet methods of reaching agreement, once the lines are drawn, are not very potent.

Historically, in Western thought the issue of relativism became more urgent with the growth of empire, bringing with it colonialism and exploration of the earth. With the corresponding growth of anthropological knowledge it could no longer be easily maintained that "our" Western way of doing things is normal. And that remains the case. In a sense, cultural relativism was a "live and let live" approach, and it was an attractive approach for approximately the first half of this century.

Now that the recognition of diversity has been accomplished and the limits of the earth established, there are few unknown places that can be marked on the map of the world with the warning, "Here be dragons." For the most part, we know what is out there. Our world now grows, not more diverse, but smaller and in many ways more homogeneous. By the same token, crises grow larger. We can speak knowledgeably of genocide, of the death of the oceans, of planetary issues such as global warming and the ozone layer, deforestation, and desertification. The world-wide movement for the protection of human rights does not concede much to moral relativism: Contextual determination and historicism are not relativistic.

Social existence provides an arena in which different moralities can confront each other and contend. From this perspective, the values of freedom and truth are essential for permitting a valid confrontation. But from the point of view of extreme relativism, or what is now sometimes called constructivism, there is no such thing as an empirically, logically, or morally valid resolution of differences. If that is the case, freedom and truth-seeking are almost worthless.

Moral relativism boils down to assertions that certain serious questions concerning human conduct are undecidable, or better, that all such decisions rest on sets of presuppositions, some of which are fatally moot. We can, however, look at things in another way. There are many situations in which we may not have unassailable grounds for choosing the best course of action, but it is relatively easy to decide that there are certain acts which will not satisfy our goals or preserve our moral values (e.g., capital punishment by hydrogen bomb, or capital punishment of babies for soiling their diapers).

This is to say little more than Newell and Simon (1972) did in making the distinction between optimizing and satisficing. In their vocabulary, "the satisficing heuristic ... accepts the first move meeting prior expectations" (p. 703). There are many problems, including some if not all moral issues, where it is difficult or impossible to decide on the optimal approach but possible to see that some solutions are clearly unsatisfactory. This leaves a middle ground—the problem of deciding that solutions which seem satisfactory really are so, or at least that they are not disastrous.

So, to see things clearly, all moral problems must be seen relative to their total contexts. This need not leave us helpless in a stew of utter relativism. We have the possibility of what has been called "limited rationality." In the cognitive domain, I have conducted a series of experiments that bear on this issue (Gruber 1990b). Two people are confronted with a situation in which they see different shadows of the same object. Their task is to collaborate in discovering what object might cast those two shadows. Sometimes their initial behavior is distressingly egocentric, but eventually most adults and adolescents work out a collaborative way of sharing their disparate points of view and arriving at a correct synthesis not available from only one perspective. Some pairs, especially among the adults, even arrive at the happy conclusion that more than one solution is possible. But it must be emphasized that this is not an "anything goes" result. For example, no one ever proposes that a square shadow could be cast on a flat surface by a spherical object. Discussions of human nature, such as Asch's, may search for a rather modest solution—not how to find the best or only possible course of action, but how to clarify the necessary constraints on all moral codes, making some courses viable and others not. A society that uses infanticide as a means of population control may well be viable; but a society that does not rear enough of its children to become surviving and reproducing adults will surely disappear.

A seeming exception to this rule is the society of Shakers. By taking and observing their vows of celibacy they guarantee that they cannot replenish their numbers through sexual reproduction. For a long time they met this difficulty by recruiting members from the larger society. They maintained a high aesthetic ideal expressed through their wonderful craftsmanship, showing the heights to which plain people could rise.

The Shaker story brings out an important feature of Utopian societies. They may be seen as social experiments, like an image-enhancing technique, that clarify certain features of social existence. To think clearly, physical scientists absolutely must use idealizations such as frictionless motion and perfectly elastic collisions, phenomena that are not attainable in the real physical world.

Utopian thought can be treated as a form of idealization in the social and moral domain. Just as physicists "fail" when they try to embody their idealizations in the real world, utopians fail too. And from these failures, essential to human thought, much is learned. Likewise, rather than thinking of the perplexities of moral life as demonstrating a species-wide impotence, we can think of the great panorama of human societies as an arena in which our species is learning how to live. Whether or not we can learn quickly and well enough remains to be seen.

## MORAL THOUGHT AND CREATIVE MORAL ACTION

Many psychological processes entail reducing the number of possibilities. In the perceptual phenomenon known as "shape constancy," as a circular object such as a dinner plate is moved, its retinal image can project an infinitude of retinal images—circular, elliptical, even a straight line—but the observer sees only one object: "plate." We can think innumerable thoughts, entertain a large number of possibilities, but we can act on only one or a very few. In fact, of course, some individuals are particularly reflective, spending much time and effort inventing and mulling over possibilities while others move more quickly and with less ado into action.

Colby and Damon (1992), in their noteworthy study of moral exemplars, did not choose as their subjects individuals who were eminent thinkers but people who were admirable actors, thus "moral exemplars." This research strategy raises interesting questions. The motto, widespread in today's environmental movement, "Think Globally, Act Locally," is not only a prescription—it sketches what is possible for most people. By choosing as their subjects people whose lives are devoted to extraordinary moral action, Colby and Damon were almost certain to choose exemplars whose actual missions or projects were local rather than global. By choosing actors rather than thinkers, they chose exemplars who were not necessarily reflective or even deeply concerned with reflection. As they pointed out

> moral reasoning alone does not tell us much about a person's actual social behavior. After decades of moral judgment research, we are still highly uncertain about the connection between reflection and everyday social conduct. (Colby and Damon 1992, 8)

The example of those moral exemplars who act spontaneously, without hesitation or reflection on matters of principle, can even be elevated to the level of a special virtue: Moral exemplars do not hesitate; they are not caught on the horns of moral dilemmas. The course they must follow is clear to them: when the refugees knock, they must be hidden. Having thus no choice, the moral exemplars have no sense of themselves as heroes. These ideas occur both in Colby and Damon's work and in the Oliners' (1988).

Finally, by choosing effective, *successful* actors in the U.S., Colby and Damon almost guaranteed that their exemplars did not attempt revolutionary missions. The work of their exemplars could be assimilated within the contemporary American context. By the same token, these individuals are not necessarily highly creative, even within the sphere of their exemplary conduct. After all, feeding the hungry is not a new idea.

It should be added, however, that although they explicitly avoided the criterion of creativity in choosing their exemplars, there was certainly room for ingenuity and extraordinary persistence—two evident features of creative work—in most of the missions Colby and Damon described. Moreover, although their sample was limited as described above, Colby and Damon's interests ranged more widely and they drew on other sources, including Gardner's account of Gandhi's life (1993b), excerpted in this collection. They quoted a telling remark by Andrei Sakharov, Soviet physicist, dissident, and Nobel Peace Prize laureate, on the importance of a vision that goes beyond the limits of the possible:

> There is a need to create ideals, even though one can't see a route by which to achieve them; because if there are no ideals there can be no hope, and then one is completely in the dark, in a hopeless, blind alley.
> (Colby and Damon 1992, 20)

Thus, although moral actors may not have a conscious experience of reflection and choice, it seems plausible to suppose that they are guided by some vision of the world as it should and could be.

There is a connection between the issue of moral relativism and the pathway from moral thought to moral conduct. People who are interested in moral action *must* find a basis for choice among alternative courses of action. And in serious situations they must be satisfied enough with their choice to have the confidence necessary for difficult tasks. On the other hand, people who accept or even prefer inaction to action can afford extremes of constructivism and relativism that make the moral foundations of all purposeful conduct questionable. Innovative behavior would be the most suspect, because there is—typically, in prolonged, early stages—not even the epistemologically suspect support of consensus. Gandhi's life brings out the strong pressures that were brought against his efforts to work out new courses of action.

Piaget's pioneering work dealt both with moral judgment and moral conduct, the former through clinical interviews with children about moral dilemmas and the latter through observing children at play in rule-governed games. In spite of this auspicious combination, most empirical work on the psychology of morality has been about the development of children's moral reasoning. If we are interested in moral conduct, and especially adult moral conduct concerning serious issues, the laboratory is a very constraining environment.

There have been, however, notable exceptions. Among the best known is Milgram's (1964, 1965) study of college students' willingness to perform an act of dubious morality (i.e., administer severe electric shocks to fellow students in the context of a realistically staged learning experiment). It should be remembered that Milgram's chief finding was that the presence of confederates (pseudo-subjects) was very effective: If the confederates urged administering ever stronger shocks, the actual subject did so; if the confederates protested against instructions to administer strong shocks, the subject joined the revolt and refused to go on.

In spite of some dramatically instructive experiments, investigators interested in adult moral conduct have been drawn out of the laboratory and toward the case study method, which is paramount if we are interested not in single moral acts which can be studied in the laboratory but in the conduct and unfolding of a moral life. Still, we are only at the beginning of the integration of biographical and psychological knowledge necessary to understand moral creativity.

## CONCLUSION: SCIENCE AND SOCIETY

In the contemporary world, scientific knowledge is increasingly important for the solution of numerous problems, including the kind I have been referring to under the heading of "planetary morality." Yet not much attention has been given to the means by which social policy needs and scientific knowledge can be brought together. Social scientists may have a special role to play in designing circumstances favorable to such integrations.

Hammond et al. (1992) pointed out that while there is considerable uncertainty in expert judgments about matters of social policy, there are rational means for reducing this uncertainty. The nub of their proposal was that the inputs by policy makers and scientists to any decision process should be sharply separated during an initial phase and only then integrated to produce a decision. Hammond et al. made explicit suggestions as to the means of combining these complex inputs. As to the selection of policy makers they were not explicit, but seemed to propose that every group concerned be given a voice. It is the task of the scientists to provide the facts and the task of the community involved to provide the values. Hammond et al. gave instructive examples from real cases, such as weather forecasting in relation to airfield management, selection of dam sites, and choice of the bullets to be used by a major police force.

It should be noted that decision theorists, in a fashion similar to moral judgment theorists and to Colby and Damon in their new work on moral exemplars, are relatively silent on the problem of creativity. To be sure, alternatives and their consequences should be clarified and evaluated by the most rational scrutiny possible. When the alternative courses of action are given, moral exemplars can do their saintly best, and scientists and policy makers their rational best.

In a time of multiple crises, however, our knowledge of the possible alternatives and of their combined consequences has its limits, and it is at this point that creativity is called for: to scan the horizon for new alternatives, to detect and amplify them, to clarify and perfect them to the point where they enter the arena of limited rationality, the world of the possible. The improvement of means for rationally combining the knowledge of scientists and policy makers would itself be a major creative act.

# Creativity and Human Survival

From *Children of Hiroshima*:

*I steal a glance at my arm under the sleeve—*
*Death's spot is not there yet.*
From "Blood," a poem by Koichi Tokuno, 11th grade boy (5th grade at the time the atom bomb fell).

*In the right hand we have penicillin and streptomycin; in the left hand the atom and the hydrogen bomb. Now is the time for the people of the world to consider more rationally this contradiction.*
From essay by Yoshuko Uchimura, 12th grade girl (6th grade at the time of the bomb).

The study of creative work is fascinating and rewarding in its own right, but it may also provide a valuable springboard for some useful reflections on the greatest moral question of our age—how to work effectively for the survival of our species.

As the creative life unfolds, work proceeds on many fronts; this is expressed in the diversity of the creator's network of enterprise: the work is organized in hierarchical structures—problems within tasks, tasks within projects, and projects within enterprises. The creator must not only organize the work itself but must manage the diverse demands of a creative life. Work and life go forward within the bounds of constraints that can be divided into two kinds—what can be done and what should be done. These can be expressed as the claims of ability and possibility on the one hand, and the claim of morality and desirability on the other. In this chapter I explore the claim of morality on the creative person.

Unlike the other chapters in this book, this exploration is not so much about creative work itself as it is about an aspect of the creative life: how creative people manage to live with themselves in a troubled world. To be sure, the task of making something new sometimes requires withdrawal from the world, but the resulting seclusion is not something given to the creator. It is hard won and often tenuous. And, often enough, creative work goes on amid the hurly-burly.

We do not find one pattern, one special way of relating to the world, that characterizes the creative person. Here too, as with other aspects of creative work, the watchword is variability. A glance at some of the people examined in this book emphasizes this point.

Lavoisier was guillotined during the French Revolution; ironically, he was not particularly antirevolutionary. Wordsworth evolved from an ardent supporter to a bitter critic of the same revolution. He lived most of his life in relative isolation in rural England.

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Darwin did his most seminal theoretical work as a young man living in London, but spent the rest of his adult life in a country home outside the city. Although he described himself as "Liberal or Radical," he was not particularly involved politically. Nevertheless, the meat of his thought was dangerous, and expressing it in Victorian England was a courageous political act.

Faraday's theoretical and experimental work made the electric generator possible, but he did not pursue the practical applications of his discoveries. When Gladston saw Faraday's laboratory demonstrations, the story goes, he asked about their utility. Faraday replied, "Of what use is a baby?"

In contrast, Woodward's chemical syntheses were of such immediate practical value that a major pharmaceutical company gave him a large laboratory in Switzerland to supplement the facilities he had at Harvard. Most likely, he could have pursued his abstract theoretical aims without doing work of direct practical significance. But he obviously had a nose for the practical, and over and over did work that bettered the human condition—all without any political or moral rhetoric or fanfare.

Einstein's work was at the outer extreme of abstractness, yet it turned out to have immense practical significance. Although for the most part he lived a life of quiet contemplation, he never forgot the world outside and was a life-long, outspoken pacifist. William James, too, was a pacifist, and for a time vice president of the Anti-Imperialist League, mobilizing political sentiment against U.S. incursions into Latin America.

Richardson was not a political activist. But in her weekly column in the *Dental Record* she often commented on social issues. More important, her major work, *Pilgrimage*, is an explicitly feminist work, and she counted the radical suffragettes among her friends. Perhaps the turning inward that characterized her work and other's was motivated by disenchantment with the promise of ceaseless progress that attracted previous generations.

Piaget described himself (in an interview with me) as "always on the Left." But in fact he avoided political activity, except for helping some colleagues when they had difficulties with various repressive regimes around the world. Nevertheless, his work has had important social consequences, perhaps the most important of which is our respect for the child as a thinking person.

But our examination of the social entailments of creative lives should not be limited to the fairly direct connections I have been citing. Even in its most other-worldly forms, creative work is a celebration of life. And even criticism is a form of celebration. When William Blake wrote the lines, "The Harlot's cry from Street to Street shall weave Old England's winding Sheet," his criticism of the exploitation of prostitutes was part of his veneration of love.

Nin wrote so sensuously and frankly about sexual experience that she projected a radical image. But raised in a traditional Latin Catholic family and married to a banker for many years, she was not conventionally radical or otherwise politically involved. She did, however, commit herself to two movements that have done much to influence twentieth-century culture. In the 1920s she was part of the surrealist movement in Paris, and in the 1960s she was involved in the women's movement. In the sense that she personified the 1960s' idea that "personal is political," she became a role model for many younger women.

Still others possess an extreme attitude that in times of crisis art should, above all things, mobilize people for struggle. This is suggested in a recent article about Chekhov by the Soviet poet, Andrei Voznesensky (1988):

> Who has time for "The Cherry Orchard" when the orchards near Chernobyl are turning black?

## CREATIVITY AND MORALITY

Our conceptions of creativity and morality are intertwined in a number of ways. First, it is widely believed that a creative person ought to exercise his or her gifts. Second, we often act as though creators are exempt from normal moral standards because they are driven by special inner necessities and must express their creative impulses. Third, there may be special kinds of creativity: extraordinary moral perceptiveness and extraordinary moral responsibility (Gruber 1985d).

At once we see that the indispensable middle term between creativity and morality is freedom. We can hardly speak of a moral act if the actor has no choice. Creative work also requires inner freedom. Although we would like to believe, quite simply, that freedom of expression favors creativity, history makes clear that creative work often proceeds successfully under oppressive outward conditions indeed often in conscious, active opposition to them.

Creative work must be in some ways kindred to the world, if not the world as it is, then the world as it will or might be. It flows out of that world and it flows back into it. Thus the creative person, to carry out the responsibility to self, the responsibility for inner integrity, must also in some way be responsive to the world.

Part of the creator's task, then, is to work out these sometimes conflicting demands of personal freedom and social responsibility. But there can be no permanent solution. As history shambles along, the shape of the problem changes. Both opportunities and constraints evolve. Picasso's *Guernica* is this century's great visual antiwar statement, but the destruction of a city is what made it possible (Arnheim 1962). Today's world gives this idea of changing demands a special point. A creator working with the next generation in mind (so soon upon us!) must believe that there will be a next generation. The danger of nuclear war and other planetary threats put that belief in jeopardy.

Difficult moral problems require creative work. Every proposal that something ought to be done implies that it is possible. But how do we know what can be done? Only by pushing to the very limits of the possible (Gruber 1985e, 1986b). The problems we have in mind are not the easy ones with obvious solutions, but the most important and most intractable ones. These deserve and require our most creative efforts. Thus "ought" implies "can" implies "create!"

In the thermonuclear age every corner of life is called into question. The power of modern technology to threaten our home, the earth, through war and other means touches everything—the air, the sea, the forests, and every living creature. We speak of the "thermonuclear" age, because nuclear war remains the greatest single danger, but the term is really a shorthand for something much wider: the worldwide, wild, undisciplined growth of technology without corresponding social controls, the aggregate threat to life on our planet resulting from the behavior of our civilization.

## THE TASK OF PROTECTING OUR PLANET FROM OURSELVES

The very breadth of the problem means that there are openings for every kind and every level of creative effort. The following brief discussion is intended mainly to underline the idea that almost everyone has a part to play in this effort.

### *Clarifying the Threat*

*An Unintentionally Demonic Collaboration*. As long ago as 1909, Frederick Soddy, later a Nobel Prize winner in chemistry, wrote *Interpretation of Radium* (1909), a popular account of what was then known about radiation and the enormous energy of the atom. H. G. Wells read it and in 1910 wrote *The World Set Free* (1910), a novel about an atomic war and the destruction of civilization. In the 1930s, the brilliant Hungarian physicist, Leo Szilard, read the book, became convinced of the feasibility of making atomic weapons, and began to campaign among his colleagues against taking research in that direction. A little later, in 1939, moved by the fear that the Nazis would develop an atom bomb first, Szilard changed his ground. He was one of a few who were instrumental in framing the letter signed by Einstein that persuaded President Roosevelt to authorize the first moves that eventually led to the atom bomb. An international financier, Alexander Sachs, one of Roosevelt's advisors, helped gain access to the White House. Thus scientists, writers, politicians, and others played their part in what appeared to be a purely technical development.

Today the same broad-spectrum creative collaboration is needed to guide the course of events in another direction. But to have any chance of succeeding, it must be planful, steady work. Is it too much to imagine a "Brooklyn Project" for peace-equal in magnitude, intensity, and creativity, but not necessarily in form, to the gigantesque, military-dominated Manhattan project that made the atom bomb? The idea of naming the project for planetary survival after my birthplace stirs a primitive chord in me. I hope you name it after yours.

*Escalation Processes*. The familiar story of the atom bomb is one among many that illustrate how escalation works. At first Szilard, Fermi, and many of their colleagues were against work that might lead to an atomic weapon. Ultimately they changed their minds because of their perception of enemy capacities. This perception was, in turn, based largely on an extrapolation of their knowledge of friendly capacities. In 1950, a similar sequence of events persuaded some scientists to reverse their opposition to the development of the hydrogen bomb, infinitely more dangerous, and to collaborate in the project.

There is almost always, within any system for research and development, a pressure to increase human capacity to manipulate nature. If another system is perceived as "the enemy," then similar intentions and capacities will be imputed to it. Thus policies are based not only on what the potential enemy actually does, but also on what it might do—and our conception of this is based on a particular aspect of self-knowledge, our own thirst for progress. Ergo, the power of escalation that is always with us.

Students of creativity are necessarily interested in systems that escalate—deviation-amplifying systems. Escalation processes are not intrinsically good or bad; they can be gloriously creative or they can be unbelievably destructive. They are, of course, bound to entail some unknown risk, since in principle they change the established order of things. Perhaps we can learn how to apply our knowledge about creative work to understand how escalation processes become dangerous, and how to redirect them.

### *The Image of Humanity*

All of the arts contribute to our image of humanity, and not always on the side of peace. Beethoven, in the Eroica symphony, celebrated, as he thought, the liberating warrior Napoleon. We can agree that wars begin in the minds of men, but it is not easy to see how to change those minds. Exposing the horrors of war is clearly not adequate. In his great essay, *The Moral Equivalent of War*, William James (1995) said "the horror makes the thrill." And every day's television programming, with its steady stream of violent images, exploits that principle. The mood of the media is hard.

Yet there is hope. Antiwar literature like Remarque's *All Quiet on the Western Front* and Vonnegut's *Slaughterhouse Five* has found an enormous audience. Likewise antimilitarist works such as Hasek's *The Good Soldier Schweik* and Mozart's *Magic Flute*, a Utopian tale, still delight.

What can we expect of the arts? A great outpouring of works engendering new hope and new images, world consciousness, planetary solidarity? This would help. If the artists themselves were determined enough, and if others helped in a steady, deliberate way, they might catalyze a shift toward a new mood. The Manhattan Project involved no artists. The Brooklyn Project would need them.

Ours is a great civilization. May there always be poets to sing its praises! But it is deeply flawed by a collection of social arrangements that ignores our need for harmony with nature and with each other, that accentuates the drive for power—power over other individuals, power over other countries, power over nature. In *Ozymandias* Shelley evoked the ruins of such a world:

> Two vast and trunkless legs of stone
> Stand in the desert ... Near them, on the sand,
> Half sunk, a shattered visage lies, whose frown,
> And wrinkled lip, and sneer of cold command,
> Tell that its sculptor well those passions read
> And on the pedestal these words appear:
> "My name is Ozymandias, king of kings:
> Look on my works, ye Mighty, and despair!"
> Nothing beside remains.
> (Rogers 1975, 319-320)

## EARTH OUR HOME

We need to work toward new political forms, new ways of doing science and of monitoring technological change, new images of humanity that emphasize the ideal of harmony in nature rather than dominion over it.

The *Home Planet* (Kelley 1988) is a book of memories and reflections by astronauts of all countries. These are people who have been where the differences between Us and Them disappear:

> The first day or so we all pointed to our countries. The third or fourth day we were pointing to our continents. By the fifth day we were aware of only one Earth. (Astronaut Sultan Bin Salman Al-Saud)
> It does not matter what country you look at. We are all Earth's children, and we should treat her as our Mother. (Astronaut Alexandr Alexandrov)

## TASK-EGO-WORLD

In Gruber (1989c) I alluded briefly to a prime motivational distinction between task-oriented and ego-oriented behavior. Ego-orientation, or extrinsic motivation, refers to an attitude toward work that is motivated by desire for rewards not inherent in the task itself, rewards such as recognition, prestige, prizes, money, privileges, and power. Task-orientation, or intrinsic motivation, refers to an attitude toward work that is motivated by the intrinsic nature or demand-character of the task itself.

Several intellectual traditions—Gestalt theory, Piagetian developmental theory, Veblen's idea of the instinct of workmanship, and an antibourgeois rejection of the marketplace mind—all converge upon the expectation that the creative person will be primarily task-oriented. Amabile's experimental research has given strong support to that hypothesis (1983). Once confronted with a task and committed to it, to be engrossed in it, to be caught up in the work, is a good augury. Moreover, considerable experimental evidence has indicated that, at least in the short time of a laboratory experiment, once intrinsic motivation is established it is best left alone: introducing the prospect of reward may actually undermine creative activity (Amabile et al. 1986). On the other hand, if we look at motivation over the time span of a creative career, we must introduce some other considerations.

As we have seen, each creative person develops a network of enterprise. In other words, at any given time a number of projects may be under way, each belonging to different enterprises. Each one will have a different motivational profile. The creator will be more invested in the finished product envisaged for one project but more intrigued by the immediate problems presented by another. He or she may expect greater immediate, short-term recognition from completing one project but a deeper long-term admiration from another. Thus the creative person must manage the relationships between motivation and conduct, continually assessing the whole situation—abilities and opportunities, progress already accomplished, and the motivational profile of each undertaking.

To these complexities I would add another. The dichotomy between task- and ego-orientations is inadequate. There is a third actor in the play of motives, the world. One is not always free to choose the most alluring task, as governed by task- and ego-orientations. Extrinsic motivation must be subdivided into two categories, ego-orientation and world-orientation.

The world makes its claim on us. True, not everyone responds in the same way. Task-orientation, ego-orientation, and world-orientation each have their appeals. Every creative person must shape his or her own motivational profile. Historically, the task-ego distinction has been thought adequate for many purposes. Now our planetary situation is more desperate and the world makes more urgent claims on creative people everywhere.

It should be emphasized that these motivational orientations—task, ego, world—are not mutually exclusive. They probably all operate together. What distinguishes individuals is not all-or-none choices of one orientation or another, but different motivational profiles. Moreover, the relative salience of motives can shift, depending on circumstances and on the work itself. Let us suppose that each of these orientations is coupled with its typical emotional tone: task-engrossment; ego-ambition; world-duty. Then we would expect that the ebb and flow of these motivational patterns would produce changing pattern of emotional experience.

"World-orientation" may take many forms, even the simple and direct altruistic helping of another. In discussions of altruism, it is sometimes suggested that apparently selfless behavior is, in effect, a sham—that the altruist actually behaves altruistically for self-centered reasons, such as increasing self-esteem or avoiding guilt. This may sometimes be the case. But there is mounting evidence that altruistic behavior can result directly from fellow feeling for the other person, or as one study concluded, "empathic emotion evokes altruistic motivation" (Batson et al. 1988).

Elsewhere (Gruber 1987a) I have argued that most altruistic behavior is limited to corrective action such as alleviating suffering. It can only occur when there is a discrepancy between the fortunes of the beneficiary and those of the benefactor, but it does not envisage eliminating this gap; it hopes only to lessen it. Indeed, part of the ordinary moral responsibility of everyday life is to behave altruistically in this sense, from time to time, when the situation demands it.

On the other hand, we can envisage and identify cases of "creative altruism" in which a person displays extraordinary moral responsibility, devoting a significant portion of time and energy to some project transcending immediate need and experience. Creative altruism, when it goes the limit, strives to eliminate the cause of suffering, to change the world, to change the fate of the earth.

## WHAT IS POSSIBLE?

The newspapers routinely carry items evoking the fear that modern civilization is less the cornucopia of marvelous technology and more the Pandora Box of chronic warfare and untrammeled destruction of nature. If one war peters out, another explodes; if one environmental threat is dampened, another comes to a boil. The task of defending the earth has become endless.

Confronted with an infinite task, the finite individual may well feel impotent. You might ask, how can anything one does make a difference? I offer some thoughts on the strategy you might adopt, a strategy that bears some resemblance to the way creative people work:

Take a developmental approach—start with what seems within grasp, then strive to expand the zone of the possible. Carve out a finite domain within which change can be detected, success identified. Try to define certain invariants, conditions that seem imperative, then look for flexible ways of maintaining these constants. There is probably no giant step that represents the solution, but very many one-percent steps, or even smaller. Choose a project and invent the steps that will be within your reach.

Go beyond your own limitations by finding friends, neighbors, and colleagues who also want to defend their planet. Multiply your creative resources by inventing a project together with others. Be realistic about time. If you are not prepared to devote your whole life to your project, set a definite goal, such as one-half day per week. I think of this as tithing, the custom of giving one-tenth of one's income to one's church. As one strand in my network of enterprise, the defense of my planet seems to be worth about one day per week. Perhaps the goal has infinite value and ought therefore to merit 100 percent of one's energies. But at least I can tell myself that if I am regular about one day per week, and if I work with others, a project of some worth can be pursued.

Ecologically minded people sometimes capture a similar way of thought in the phrase, "think globally, act locally." Once a certain level of world consciousness has been achieved, this is a valuable strategy. But that consciousness spreads slowly, perhaps not fast enough to counteract the exponential growth of the various maladies of the earth. I predict that a different pattern will take hold. More and more people will respond to some immediate problem in their own milieu, and that will lead them to consider the contradiction between human intelligence and civilization's crazy behavior. They will act locally, then think globally.

A word on one last troubling question. Suppose a person gets involved in using his or her creative energies to developing this world consciousness or to work on some local problem connected with planetary defense. If the problems are endless, if Pandora's Box is bottomless, then won't such a commitment simply make one miserable? Won't it drain creative energies in a futile effort?

The question calls to mind Camus' essay, *The Myth of Sisyphus*, about the man who refused to die. As Camus (1955) recounts the Greek myth, Sisyphus is condemned by the gods to roll a heavy rock up a steep hill; when it reaches the top, it rolls down, and he must start over again. Camus puts himself in Sisyphus' place and wonders if there is any point in this labor, would not death be better? Camus concludes his reflection: "Sisyphus teaches the higher fidelity that negates the gods and raises rocks ... This universe henceforth without a master seems to him neither sterile nor futile ... The struggle itself toward the heights is enough to fill a man's heart. One must imagine Sisyphus happy."

# CHAPTER 8

# PEACE AND FURTHER CONDITIONS FOR HUMAN WELFARE

Thinking about peace calls up thinking about war and the beast in us, though it is by no means obvious that war is evil. As William James discussed in his famous essay *The Moral Equivalent of War* (1995), war can be, and indeed, has been seen as invigorating and heroic. If it is true, as James proposed, that sports and festivals can substitute for war, perhaps the converse is unfortunately also true: war can replace sports in the national repertoire. From another perspective, war can be seen as a business enterprise, making fortunes for some and misfortune for others. So it is clear that one can study and puzzle over the social functions of war and whether war is necessarily evil and, if so, whether it is sometimes a necessary evil.

## HISTORY AND THE PEACE MOVEMENT

As World War II was drawing to a close, a group of distinguished psychologists and other social scientists undertook to explore the questions: Is war inevitable because it is built into our genetic heritage? If not, what can be done to prevent future wars, especially global wars? The group produced an important book *Human Nature and Enduring Peace* (Murphy 1945). (This book was sponsored by SPSSI—*The Society for the Psychological Study of Social Issues*, a division of the American Psychological Association). Not surprisingly, the conclusion was that yes, war is avoidable if certain things are done.

This document was drawn up in 1944, just a year before the Hiroshima bomb and about a year before the worst of the Nazi genocide came to light. It seems anachronistic now and certainly outmoded in many respects: For example, the 1944 manifesto made no mention of Africa (South Africa was seen as a hopeless case, the rest of the continent non-existent); India achieved self-government a few years later; China's Communist revolution succeeded in 1947; and since then we have manufactured the hydrogen bomb, revived chemical warfare, and are overwhelming the global environment.

The repeated remaking of the political, economic, and military maps of the world during the twentieth century left the peace movement in some disarray, at least as I experienced it. All through my adolescence and young adulthood I took it for granted that war was bad but necessary in some situations—the *just war* ideology. I was fourteen when the Spanish war began and did not question these ideals. It was not until Hiroshima in 1945 that I experienced serious doubt. But when *The American League against War and Fascism* became *The League for Peace and Democracy,* linking the movement against war with the movement against fascism, we unwittingly foreclosed examination of the nature of war, leaving a silence which prevails today.

To some extent the activist spirit so evident in the 1960s has been assimilated into the Green movement. While this may be all to the good, it is no substitute for renewing our energy in the struggle for peace in the world.

From the end of World War II until about 1980, all thought about war and peace was dominated by the idea of a two-player, USA-USSR, end-game, with nuclear weaponry as the threat and total destruction at stake. But a new, vastly more complicated and unstable configuration has now emerged. There are today eight or more countries with nuclear weapons. Indeed, there are many more nations in existence—more than twice as many—as there were at the end of World War II, and many more national identities to die for. With the demise of the Soviet Union, there is one superpower facing a bewildering assortment of other powers, many of which have enormous destructive capacity. Furthermore, nuclear arsenals have been superseded by biological and chemical weapons. With these, as well as with the spread of sophisticated and more powerful conventional weapons, the line between war and terrorism has become increasingly blurred.

The peace movement is very quiet (at the time of the Gulf war it was, at least in the United States, nearly quiescent). Peace efforts, whether governmental or private, are always precarious, are always more fragile than belligerence, always in danger of evaporating, whether in Ireland, the Middle East, or Africa.

What to do has become less and less clear. For regionally organized groups to become active with implications for the world as a whole is more and more farfetched. Perhaps, as the world undergoes *globalization* commercially, it is becoming more fragmented and locally isolated in its friend-enemy thinking, losing sight more and more of the good of the larger community and the world.

After Hiroshima, Einstein lamented that for our world to survive, we would need a whole new way of thinking. Then came Nagasaki, and the revelations of the Holocaust.

I will never forget the moment we got the news of the bombing of Hiroshima. I was with a group of soldiers preparing for the invasion of Japan. My comrades in arms were elated—we had been spared. But I could not take it in. One hundred thousand people killed in one blow! I sat apart and mourned. Eventually I met a few others like me. Sickened.

Under such circumstances, the *Cold War* began. McCarthyism, thinking the unthinkable, the Nth-country problem, the *Berlin Wall*, the execution of the Rosenbergs, the anti-ballistic missile and the anti-ABM movement, the hydrogen bomb, Rosa Parks and the Montgomery Bus Boycott, the revelations of Babi Yar and the Gulag Archipelago, the assassinations of J. F. Kennedy, R. F. Kennedy and Martin Luther King, the rise of the women's movement, the war in Vietnam—these were some of the pre-occupations of liberals, leftists and pacifists the world over. As for me, I demonstrated and organized. For the most part, I kept my activities within professional circles, aiming to transform the way concerned social scientists go about their work. It was in this context that Wolfgang Edelstein invited me to speak about optimism. I am still somewhat dismayed at the results of my reflections: I was no longer an optimist—and am only less so today.

* * * *

We began this book with a paradox inherent in the history of science: How can we work toward the novelty necessary for discovery while still maintaining a stable point of view? Looking at the world as we know it now, the forces of destruction still outrun the forces of peace. The least we can do is not deny our anger and let our outrage prompt us to action. We began with one paradox and end with another: The idea that our species, with its almost miraculous intelligence, is leading the way into darkness.

We also opened this book with Wordsworth's tranquil image of dark, invisible workmanship that reconciles discordant elements and makes them move in one society. Now we must discard our tranquility and insist upon our rage. As the poet Dylan Thomas urged his own father, we must urge the whole human family: "Rage, rage against the dying of the light."

# Man or Megaperson?

Talk of the psychopathology of war may conjure up images of frankly psychotic individuals, themselves lost to the world, suddenly possessed of the means to destroy it. We should not entirely dismiss this possibility, for although the government of the major powers do not now suffer as much as they did a few years ago from the problem of senile psychosis, for example, the history of political power—from Nero to Hitler—has never been free of the suspicion of outright individual insanity.

But that is hardly the main problem. A greater threat is a form of collective insanity in which we prepare to kill tens or hundreds of millions of people in other countries with no hope of gaining anything from it, except, supposedly, a slightly lower casualty rate in our own country.

Sober estimates of the number of deaths occurring in the first two months after one or two days of thermonuclear war run from twenty-five percent to seventy-five percent of our population, the higher estimates being the more plausible. The political system that would emerge from the shelters with the survivors would be determined not so much by our political heritage as by the emergency conditions of life they would face for many years. Life might be distinguished from death, but victory would be indistinguishable from defeat.

Faced with such prospects, it is totally irrational to contemplate thermonuclear war as a defense of our present way of life or as a solution of present political problems.

The peculiar thing about this collectivity of death is that the individuals preparing it are, for the most part, individually sane and intelligent. The scientists on both sides are sound, the military men are sound, the statesmen likewise. (I repeat, for the most part.) The individuals are sound, but the combination is sick.

What is the essence of this pathology?

Its essence is the failure of civilized man to evolve appropriate new social institutions to manage a powerful new technology. Society changes fairly slowly. Technology changes rapidly.

This unbalanced growth is especially true today, when vast sums are spent on research to find new ways of changing technology, but those in charge of spending these funds, the political leaders of each country, have no desire to provoke important changes in the societies they enjoy governing.

In the process of biological evolution the conditions favoring the extinction of a species are extreme evolution along some lines of development, coupled with loss of capacity for change along other lines. The world inhabited by any species is always changing: only those species that can continue to change to meet new conditions can be expected to survive.

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Similarly, in the process of social evolution, a society that becomes overcommitted to adaptations suitable for a single historical situation may lose that capacity for change which is essential to survival.

A great deal of our thinking about international affairs is dominated by the notion that the world is divided into two great social orders, *We* and *They*, one of which will prevail. But considering their short and troubled histories, it is foolish to behave as though either of the major contending systems—*We* or *They*—can lay any settled claim to the future. Just as historians today describe the decline of feudalism and the evolution of mercantile capitalism, historians a few hundred years from now—if there are any—will describe the evolution of new social orders out of today's struggles. We cannot avoid social evolution, but we can have some effect on its course. In particular, by means of thermonuclear war, we can arrange matters so that future civilizations have little or no historical connection with *Ours*—or *Theirs*—which will have perished, leaving only remnants that no one will wish to preserve. Or, we can recognize that *We* and *They* are both but transitory phases in the social evolution of man, thus enabling ourselves to take a more detached and flexible look at the problem of international conflict. There are more alternatives than *We* or *They*, and, we need to set about looking for them.

Social scientists spend relatively little effort thinking about the future of social evolution. Much of the discussion of acculturation is overly static, in that it presupposes culture change from its primitive beginnings to a fixed endpoint: the way *We* live *Now*. Or, of course, the way *They* live *Now*. Instead, we ought to allow ourselves to think through alternative models of social evolution which combine the emergence of totally new social inventions with existing ones appropriately gathered from the totality of contemporary society. What will the area we now call the United States be like when it has a billion inhabitants, universal higher education, a twenty-hour work week, and an average longevity of one hundred years?

The study of the future is not much more speculative than the study of the past, and it might free our thinking so that we can escape from the dangerous crisis mentality in which the world is divided into two unchanging orders, *We* and *They*. George Bernard Shaw once wrote that a fanatic is a person who, having lost sight of his objectives, redoubles his efforts. I take it that our prime objectives are the preservation of human life and of the opportunity for man to evolve from where he is now to some unknown but enjoyable future. If a complex chain of thought leads to the conclusion that the wholesale destruction of human life and the reversion of human existence to the ugly aftermath of thermonuclear war is, under certain specified conditions, an acceptable solution to our problems—then there is something wrong with that chain of thought.

One difficulty in rejecting such arguments, however, is the intimidating way in which they are invested with the trappings of science: theoretical models, statistical assumptions, and computer technology. But theoretical models almost always contain errors, statistical assumptions are at best approximations, and computers very often go wrong. In scientific work, these errors are part of the game, but they are not fatal. We check and re-check our work, we test the same idea in a variety of ways, and we examine its plausibility in the light of larger conceptions.

Imagine, if you will, an electronic computer printing out the conclusion that the earth was blown up yesterday. We would automatically decide, on the basis of larger considerations, that something had gone wrong with the computer. Now if a computer tells us that we should blow up the world, or a large part of it, tomorrow, we have an equal need for a larger set of conceptions that tell us the computer is wrong.

In this sense, moral codes—such as the prohibition of genocide—are not mere emotionalism. They are rational checks on the correctness of intellectual operations. Our belief in the value of every human life is not mere liberal softness: it is the theoretical framework that tells us whether or not a strategic conclusion is within the bounds of reason.

Now, as I have said, the individuals engaged in strategic thinking are—as individuals—sane and moral men. This may suggest to you that they would not accept conclusions violating the extremely simple morality in question.

But the moral problem is not so simple. One of the great social discoveries of man is the need to struggle for what we believe, sometimes even at the cost of life itself. In the thermonuclear age, the morality of human survival confronts most sharply the morality of struggle for principle. Now, in defending a principle with your own life, the presumption is made that you preserve the principle for other men to enjoy. If, however, your struggle takes a form that kills other men by the millions and creates conditions that make the principle meaningless, your death is worthless. Therefore, forms of struggle must be found that defend the principle without destroying life itself. The failure to recognize and resolve this dilemma has led to the pathologically one-sided morality which sees thermonuclear war as a potential solution to political problems.

There is a kind of Gresham's Law about moral behavior. The number of casualties acceptable in war is determined as much by the going moral standards as by military capability. Remember, when we prepare ourselves militarily to inflict twenty-forty-sixty million casualties upon another country, we prepare them morally to inflict a like number on ourselves.

Perhaps you will have noticed that in the early part of this discussion, I permitted myself to accept an important change in fundamental moral assumptions. I spoke of the danger that our civilization might perish even though some individuals would survive. This is a profound change in the unit of strategic analysis. Those who have learned to think in terms of megaton bombs have also learned to think of survival and death in terms of megapersons. Although I like to think of myself as a modern man, I have not come that far. For me, an individual life is not a small fraction of a megaperson, it is an individual life. If we abandon that fundamental unit of moral analysis it is only to provide ourselves with a rationalization, an intellectual facade, because when all is said and done, no matter how tough we are, we have not yet learned to look squarely at the human horror of thermonuclear war.

In his book, *The Uncertain Trumpet*, General Maxwell Taylor has described the confused and shifting strategic thinking of our own security establishments—the National Security Council and the Joint Chiefs of Staff. It is probably safe to assume that the same moral and strategic confusion prevails in other countries as well. The military mind examines seriously only a very narrow range of alternatives, from limited war to unlimited war. We can help them to broaden this perspective by injecting into the public discussion a much wider range of possibilities.

The world has been playing an international game of blind man's buff but with two blind men. If the game continues, they will eventually collide, and the game will be over. So long as we maintain the thermonuclear military establishment, we perpetuate the threat of thermonuclear war. In this case, mutual deterrence is mutual madness.

We need to dismantle the thermonuclear military establishment, and if that means total disarmament, so be it. Disarmament must become a national objective. We do not yet know how to achieve it. Only through widespread discussion on an international scale will we find the way. Social scientists and other intellectuals can contribute to that end by widening the scope of the discussion—by using their own tools of trade: reading, thinking, speaking, writing. Such discussions are more than an intellectual exercise. They can be a direct demonstration of how to take disagreements off the level of violent conflict and pursue them on the level of rational discussion among rational men.

# PEACE RESEARCH, WHERE IS IT GOING?[1]

## *Optimism and the Inventor's Paradigm*

In this essay I will discuss three main points: first, the optimism that lies behind the efforts of peace researchers and the obligations that optimism entails; second, some suggestions for new lines of inquiry within prevailing research paradigms; and third, a proposal for a change toward what I call "the inventor's paradigm." Although this chapter appears in the context of a discussion among psychologists, I take it for granted that serious peace research must be an interdisciplinary affair involving all the human sciences as well as other fields.

There are some general questions of research style that must be faced if peace research is to become maximally effective. Peace research must become more future-oriented and less reactive to past events. This would mean that attention is given to the possible futures constituting the context in which the results of research would be applied. For example, the economics of scarcity may not play a large role in today's panorama of "local" wars, but when the population of the earth triples the pattern will be different. Furthermore, since peace research is chiefly a branch of applied social science, more attention must be given to defining the potential consumers of the research products and to working together with them. Are these consumers heads of state, legislators, teachers, captains of industry, workers in armament factories, peace activists, or the man and woman on the street? Different clients will be interested in different problems. I do not mean that our scientific work should be servile or client-dominated but only that the eventual consumer of research must be taken seriously into account.

### INTERLUDE ON THE PERPLEXITIES OF HUMILITY

In a recent article, James Blight has severely criticized most psychological peace researchers, whom he lumped together under the rubric of "nuclear depth psychology," as being "policy irrelevant." To become relevant, he argued, they should learn to talk the language of policy makers and they "ought to return first to the Cuban missile crisis, the closest call ever to a major nuclear war, and try to get inside the thinking of its key participants" (Blight 1987, 27). There were a number of respondents to

1. I thank Wolfgang Edelstein for encouraging me in my efforts to develop my ideas about peace and peace research. I thank Matthias Finger and Doris Wallace for their careful reading of an earlier draft and for many helpful suggestions.

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Blight's article. Of course, no one objected to the idea of reconstructing the Cuban missile crisis. But there were strenuous objections to the narrowness of his research prescription and to the arrogant tone of his remarks.

For my part, I thought the effect of the article was salutary: psychologists were vigorously and publicly arguing about the best way to do peace research. If peace research psychologists try to work with varied audiences in mind, some of them will get closer to policy makers and to technological chieftains. If their identification with the powerful grows, so may their sense of superiority as compared with their more modest colleagues, far from the seats of power. But no one should feel certain that he or she knows the best path to follow. The international war system is enormous and complex. Every facet of society is involved. The transformation of the war system into a peace system (Robert Holton's phrase) will require changes everywhere. If we already knew how to do that, you wouldn't be reading this essay and I wouldn't be writing it. As the philosopher David Hawkins once said, in difficult situations the job of a consultant is to supply the necessary Don't-Know-How. In the face of the massive and intractable threat to our planet and species, extreme modesty is called for. And therein lies one paradox, for it is not necessarily the most modest people who will make boldest conjectures, invent new approaches, and design sweeping and imaginative programs.

In this essay I address various questions that must be dealt with as the peace research movement—for it is a movement—defines itself and outlines its own future. I write in a questioning spirit, but enthusiasm sometimes overtakes me and the question marks drop out. They should be put back, liberally.

## OPTIMISM AND PEACE

The contemporary enterprise of peace research is explicitly founded on the belief that the situation of life on our planet is seriously endangered by the threat of war, especially nuclear war. It is also founded on an implicit optimism, a hope that can take one or more of three main forms:

1. *The possibility of peace*. The belief that a stable peace can be achieved, and nuclear war prevented.
2. *The efficacy of peace research*. The belief that peace research, or the application of the human sciences to issues of war and peace, can contribute to the primary goal of avoiding war.
3. *The value of understanding*. The belief that peace research, because it deals with problems of human existence under extreme conditions, can illuminate general problems of psychology and other human sciences.

Optimism of the second kind is obviously contingent on the first. But the third kind is independent of the others. Even a pessimist on the first two issues might believe that there is some intellectual or spiritual benefit in understanding the human condition, as we go down.

Optimists of the first two kinds would probably favor research projects bearing some promise of practical results: educational change, or social and political action. Optimists of the third kind might be led to probe more deeply into the *causes* of our dangerous situation. Of course, it would come as no surprise to learn that they harbored some secret hope that understanding might lead to improvement of the human prospect. As Kurt Lewin put it, there is nothing so practical as a good theory.

Optimism of the first or second kind makes a hidden assumption of the other person's rationality: if peace researchers find out something useful the knowledge will be rationally applied by those in a position to do so. For historical reasons I am skeptical about this assumption. Therefore, the last part of the essay makes a proposal—the Inventor's Paradigm—that does not depend so heavily on others to work out how to apply knowledge as it becomes available.

## TIME-SCALE AND HISTORICAL CONTEXT

In the long run we will all be dead, the Earth too. So an optimistic stance must presuppose a time-scale. For this discussion, I have in mind some period within which existing social-political arrangements, ecological conditions, and technological capabilities remain approximately the same. This gives us a far horizon of at most 100 years. We have little need to consider events beyond that time. If we could know now that we would get that far, we should count our blessings.

*Qualification*. Ecologists would be justified in querying the preceding remark. Various environmental problems may not peak for 100 years, but contemporary practices are now creating enormous difficulties for our descendants: the deterioration of the oceans, the atmosphere, and the forests. We can see right away that the world-consciousness necessary for avoiding nuclear war is closely related to the ecological sensibility necessary for protecting the planet in other ways.

Different problems require thinking on different time-scales and will therefore attract the concern of people with differing temporal horizons. Some interesting material on the temporal horizons of creative people appears in Lisl Goodman's *Death and the Creative Life* (1981).

For the near limit, we need to think at least ten years into the future. The next section explains why.

## THE IDEA OF A COMPLETE AGENDA

Like all other scientific work, peace research takes time:

1. to develop a mature and powerful agenda;
2. to formulate good questions, give them empirical form and apply plenty of ingenuity in collecting data in difficult, complex situations;
3. to transform empirical findings into comprehensive theoretical models;
4. to translate the results of all this work into proposals having practical form;
5. to persuade appropriate research consumers to make use of the fruits of this labor.

To complicate matters still further, research programs that are funded, data driven and networked into the conventional academic frenzy rarely provide enough time for that all-important ingredient:

6. reflection.

So, starting with the modest question of time-scale we have come upon a perplexing problem, the paradox of emergency. On the one hand, we need time to do and to disseminate good research. On the other hand, the research concerns a matter of extreme urgency, demanding immediate action and affecting the entire future of our species. We must avoid thinking about eternity, for that is too long to be manageable, and we must avoid thinking about tomorrow, for that is too soon to be effective. Ergo, ten-hundred years.

As an example of how the choice of time-scale may affect our thinking, consider the so-called "Nth-country problem." In the 1950s, rationalists concerned with issues of conflict set great store by the theory of games. When antagonists confront each other, game theory indicates the rational way to act, and this gives us a starting point for avoiding insane, mutually destructive policies. Almost immediately, it became apparent that determinate, rational solutions only exist for two-person games. That was all right for strategic thinking about nuclear war, since there were only two superpowers (when Britain made its bomb it could be considered part of one of the two). But some investigators worried about the Nth-country problem, because it was clear that someday N>2. Now that time is upon us; there are probably eight countries with nuclear weapons. And in the meantime we have learned from hundreds of studies of the prisoners' dilemma type that people in conflict situations don't always act rationally (big discovery!).

*Conclusions*. First, as we work out our peace research agendas we should pay careful attention to developing an appropriate relationship between the problems we are working on and our conception of the time-scale both of our research and of relevant historical processes. Second, to stand any chance of being effective the community of peace researchers must develop a comprehensive program. Vertically, each sector of such a program must go through the steps outlined above; horizontally, the program must deal with fundamental issues in a systematic way. This means having a plan and following it. Since the task is enormous, it requires cooperation of scientists with different skills and interests. To do less is probably only a pathetic cry in the wilderness—the wilderness to come.

*Qualification.* The six-step "complete agenda" should not be treated as a Procrustean bed. Ingenious thinkers will do their best to shorten the process, and that is a good thing. But the peace research community as a whole will need to find ways of putting our knowledge in order. This six-step agenda is nothing but a schematization of what most social scientists who are committed to the paradigm of data-driven research would agree upon. Later on I will propose a different paradigm, one allowing more room for invention.

## SOME DIRECTIONS FOR RESEARCH

In this section I take up a few suggestions for research that lies pretty well within existing, well developed paradigms. It goes without saying that the term "research" is not restricted only to questionnaires, interviews, experimental simulations, and other tools of empirical psychology.

Historical and anthropological surveys, for example, of the characteristics of peaceful and warlike societies fall well within the purview of established paradigms. Likewise, integrative efforts to build theoretical models synthesizing knowledge and ideas.

### *Modifying Risk Taking at the Societal Level*

War is a highly organized form of behavior, requiring ingenuity, training and planning. All wars, and the events leading up to them, involve some assessment of probable gains and losses. Every society has some standards for judging the acceptability of the risks to be taken. Although these standards may vary from one society to another, they are probably quite stable within a given culture. Elsewhere I have argued that technological change, whether it is offensive or defensive, can never improve our security because one change begets another, while technologically feasible and morally acceptable killing rates creep upward.

Herman Kahn's phrase, "thinking the unthinkable," and his defense of it, was intended to reeducate the American public, to prepare it to accept the prospect of nuclear war even if it would mean 60,000,000 deaths in one country. Among the assumptions on which the policy of mutually assured destruction (MAD) was founded, was the belief that "our" civilization would survive in a meaningful way after a war in which we destroyed "theirs."

The longevity of that policy suggests that the unthinkable did indeed become and remain thinkable. This change did not come about because a few books were written, or because of media complicity. A series of powerful experiences prepared the way

—Guernica, Dresden, the Holocaust, Hiroshima, Nagasaki, Vietnam, Cambodia—, changed our moral adaptation level, raising the acceptable kill rate far beyond previous historical experience.

Recently, the situation has changed. Not that the criterion level of acceptable destruction has moved downward, but that damage estimates have grown. This is a consequence of implacable technological progress, greater understanding of global effects as nuclear winter, and nuclear weapons proliferation. Sadly, no government anywhere on Earth has fallen because it promised its people mutually assured destruction.

*Research needs*. Better understanding of the way criteria of acceptable damage are determined, how they affect military strategy, when they become an important political factor; experimental studies of the possibility of modifying these criteria; investigation of the way these criteria interact with aspects of moral reasoning and conduct; how do people adapt to new dangers?

### *Emotion and the Threat of Nuclear War*

The prevalence of nuclear war anxiety has been the subject of a great deal of research. Most of this work has been at the level of questionnaires and interviews coded for mass data processing. And most of it has dealt with the anxiety of ordinary people, especially children and adolescents. Susan Fiske's remarkable review (1987) of the literature is almost entirely focused on the "average American citizen." She also pays some attention to peace activists and to curvivalists; but none to various groups with special competencies such as teachers, military personnel, retired officers, diplomats, politicians, scientists, and workers and executives in the armament industries. This is not intended as a criticism of Fiske; she had no choice for there has been almost no research on such groups. Yet it is these people who may have the sense of agency that the average citizen lacks (only about half of qualified American citizens even bother to vote), and the specialized knowledge and social position necessary to reverse the operation of the war system.

Abelson (1988) has recently summarized his own and other research dealing with the issue of strength of conviction. One of his findings is that people hold different types of belief with different degrees of conviction: the highest level of conviction is found for beliefs about personal morality, next come beliefs about domestic political issues, and lowest in strength of conviction are beliefs about international issues. In coping with our own inevitable ethnocentrism it should be noted that these studies are primarily restricted to one civilization in one period of its history.

In the interest of large-scale data acquisition we have probably acquired a rather shallow and denatured picture of nuclear war anxiety. The average citizen (here I follow Fiske) takes care not to think much about nuclear war and does not know very much about it. Such apathy should not be dignified with Lifton's illuminating term, "psychic numbing"—that should be reserved for profounder experiences.

I doubt if we have a deep picture of what nuclear war anxiety is like—a picture similar in depth to Sartre's description, in *Le Mur* of the emotions of men about to be executed in Spain, or to Malraux' s depiction, in *La Condition Humaine* of the emotions of an assassin about to strike. The necessary research would probably entail depth interviews and would include as subjects people seriously engaged with the problem of nuclear war, both participants in the system and its opponents. A good benchmark for defining one extreme might be the recollections reported in Children of Hiroshima as in the poem, *Blood*, written by Koichi Tokuno (eleven years old when the bomb fell, sixteen at time of writing):

> "I steal a glance at my arm, under the sleeve—
> Death's spot is not there yet."

But research on emotion, war and peace should not be limited to anxiety. We need a more complete profile of emotional reactions to playing different roles in relation to war—such as the roles of planner, perpetrator, the bereaved, or direct casualty. Besides the now familiar emphasis on anxiety, worry, and fear we need studies of other emotions such as guilt, disgust, hatred, and rage on the negative side. Positive emotions are relevant too: the sense of mastery and competence as one struggles well, affection for partners in struggle, even joy when something good happens. In my writings on creativity I have pointed out psychologists' penchant for the negative emotions, and the need to understand better how positive emotions play their role in supporting protracted creative work. It seems plausible that the emotional reactions to nuclear war go far beyond anxiety and depend on the role one plays. This idea, too, is brought out in the children's accounts in *Children of Hiroshima*.

*The Problem of Nuclear Apathy?*

Many writers have been puzzled and troubled by the findings of people who believe nuclear war to be fairly likely do almost nothing about it. Fiske has argued that this should come as no surprise to social scientists. It is simply of a piece with a general reaction to all political issues: the average citizen thinks of himself as powerless. But that cannot be the whole story. Non-average citizens also remain apathetic in the face of the nuclear threat, people who are quite accustomed to organizing and participating in all sorts of social and political activity. In today's paper, as I write, there is a story about Wellsburg (population 11,000), a town in West Virginia, where 1,000 people have mobilized to change their eating, exercise and smoking habits in order to lose weight, lower blood pressure and cholesterol levels. Storekeepers, town officials, physicians, and teachers are all playing a role in this project. One of their slogans is "Don't be a couch potato!"

Why are there so many nuclear potatoes? It is inadequate to say that the average person is apathetic. Under some conditions he and she are not. During the campaign against the installation of cruise missiles in Europe there were huge demonstrations in some countries (e.g. Finland, West Germany), while in other equally threatened countries there was silent acceptance (e.g. France).

Low estimates of the likelihood of nuclear war cannot explain these facts. Fiske's survey shows that the average American believes that the likelihood of nuclear war in his or her lifetime is greater than one chance in four. The perceived risk of incurring cancer or emphysema by smoking is probably much less than that, yet many individuals, institutions, and government agencies have taken strong actions to discourage and eliminate smoking tobacco. Here again there are striking national differences that do not yield to some simple version of the "people are apathetic" formula.

It might be argued that the people are not apathetic, they simply agree with the policy of mutually assured destruction that has been in force for so long. This might well apply to some people. But the research findings show that people who believe the nuclear war danger is high and disagree with the MAD policy also do little or nothing. It might be argued that people tend to leave issues of war and peace and foreign policy to their governments. Again, there may well be some truth in this. But during the war in Vietnam millions protested. The question remains: in the face of this exceptional threat, why the apathy?

*Research needs*. A renewed attack on this problem. Under what conditions do people awaken from their apathy? How does activism develop? What role do hedonism and private ambition play? Do people restrict their political future perspectives to their own lifetimes? What is the distinction between ordinary political apathy and psychic numbing? Is there some hidden psychic gain from living in a threatened world?

### *Activists and Other Types*

From James's *Varieties of Religious Experience* to Adorno et al.'s *The Authoritarian Personality* (1950), it has seemed practically the birthright of psychologists to provide socio-political typologies. Studies of the American draft resisters during the Vietnam war added to that literature. But there has been only the barest beginning of research into personality types in relation to contemporary nuclear war issues. Tyler and McGraw (1983) compared activists with survivalists. Elaborating that line of work, Hamilton, Chavez, and Keilin (1986) advanced an eight-type scheme, which they explored in a sample of over 300 students in a university in the western United States. For brevity here, the names they assigned to the types will suggest the fuller description the authors gave each type: eliminationist (0.0), survivalist (2.0), romanticist (5.5), stoic (6.5), hedonist (12.0, deterrentist (12.3), disarmist (20.6), altruistic fatalist (40.9). The numbers in parentheses represent the percentage of individuals falling into each type. It is notable that the percentage of "eliminationists" (those favoring a first strike to eliminate the evil enemy) was zero.

Certain aspects of the study are worth noting for their bearing on the future of peace research: the date of questionnaire administration and other pertinent information is not given, so we have no precise picture of the historical setting. This is in keeping with the typological orientation, which assumes, implicitly at least, that the goal of such research is to discover a general typology, independent of supposedly minor contextual fluctuations. The limitation of the study to American college students speaks for itself; we would certainly like to know if the zero eliminationist result holds good in the Pentagon and in Cheyenne Mountain. The authors consider their work to be exploratory, and as such it is an excellent beginning.

But I think there is a deeper problem with work of this kind. As I understand the eight-type proposal, the types are not really mutually exclusive: three of the types represent beliefs about desirable government actions; three represent beliefs about individual or small group private actions; and two represent feelings about human beings and proper attitudes to adopt. If we consider these categorizations to be independent, we arrive at 3 x 3 x 2 = 18 types. If we add a fourth categorization, images of the other, and allow three values (satanic, dangerous, benign), we arrive at 18 x 3 = 54 types.

Judging from past experience, almost certainly another team of psychologists, perhaps with subjects in another historical setting and with a different sort of subject, would discover other types, and the list would grow. Nor does using action patterns to form types lead to a stable solution because the meaning of a given action changes with historical circumstances. Thus, during the Vietnam war I found that to be an officially recognized conscientious objector might be viewed as a very extreme anti-establishment stance in one geographical region or subculture and as a capitulation to the war machine somewhere else.

Peculiarly, psychologists have a powerful penchant for typologies with very small numbers of types, ranging generally from two to eight or ten. In a neighboring discipline, biologists have no difficulty in conceiving of typologies with many thousands of types. I believe there are over 1,000 known species of cockroach, and if as a result of our technological brilliance and social stupidity they inherit the earth, they will proliferate and this species number will increase greatly.

While we may not want to go all the way with the biologists and their roaches, any typology resembling the one under discussion (which is probably the best currently available) would be very insufficiently differentiated for describing the variations to be found in various expert groups.

I have my doubts as to the ability of typological studies to deliver on the promise of a stable and manageable number of types. But if they do not pretend to be immutable or complete, they can be useful in ordering one's thought. Any movement aimed at preventing war or at constructing a peaceable world would have to recruit a great diversity of individuals, and would have to evolve arrangements permitting them to communicate and cooperate, and to make use of their distinctive skills and attitudes.

Therefore, if such movements are to be among the clients of the peace research community, it may well be that some typological studies would be a useful way to sensitize them to the varieties of nuclear age experiences.

*Research needs*. Adequately complex and historically situated studies of personality variables related to war-peace issues. There is no virtue in mere simplicity. ("as simple as possible, but no simpler"—Einstein said somewhere).

### *Extraordinary Moral Responsibility*

Without denying the importance of the average student or average citizen, it seems plausible that high level experts and talented political leaders will play an important role in determining the future course of events. The study of their personalities, attitudes, propensities, development, and manner of working should be part of the total enterprise of peace research. But it is almost certain that large-scale studies focused on the general population will fail to detect such individuals and, detected or not, fail to give them the special attention they deserve.

With this in mind I have proposed the concept of "extraordinary moral responsibility," and argued that the intensive case study method is the best way of approaching it. Most research in the field of moral development, following Piaget's lead, has been restricted to moral reasoning; the connection with moral reasoning and moral action remains relatively obscure. The term "responsibility" here refers to the idea of *taking* responsibility. In other words, there are some individuals who stand by passively when moral action is called for; there are others who accept responsibility when it is thrust on them; and there are still others who take the initiative, redefine situations as requiring action, think out possible courses of action and act.

Under the auspices of the Social Science Research Council, a series of workshops, 1983-1985, discussed this subject. The most ambitious project growing out of these meetings is William Damon's and Ann Colby's work on exceptionally moral individuals (Colby and Damon 1992). But their work is not particularly focused on moral behavior in relation to issues of war and peace. Helen Weinreich-Haste (1985), in her study of the women at Greenham Common, has discussed this issue, and I have discussed it at greater length in a book on giftedness. But on the whole, it remains an unexplored issue.

*Research Need.* Intensive study of specially chosen individuals exhibiting extraordinary moral responsibility in relation to issues of war and peace.

### *The Causes of Wars*

Oddly, psychologists have long been interested in one theory of the cause of wars, but mainly to deny it. I think it is fair to say that psychologists are agreed that wars cannot be explained as the product of the instinct of aggression. But for the most part, the discussion stops there. Psychologists claim to be interested in the causes of human behavior; war is a form of behavior; why do we not investigate its causes more vigorously?

In this section I will merely list and comment briefly on some of the major theories of the causes of wars, in the hopes of evoking interest in this question as a legitimate research goal. For such an important and complex topic, clearly requiring interdisciplinary collaboration, the present discussion is a rather undifferentiated sketch. In a more thorough treatment, it would be important to distinguish between the causes of local wars and the causes of global wars. In much present discussion, the former are assumed to be the causes of the latter, in spite of the fact that this was not the case in either World War I or World War II.

*Aggressiveness*. Most psychologists and other social scientists would now reject the idea that an instinct of aggression explains war. But there is not the same agreement on the existence of an instinct of aggression. For an excellent recent examination of this question, see Klama (1988). At the same time, there remains the possibility that culturally fostered aggressiveness may play a role in causing war.

At a first level, it seems implausible that modern warfare requires aggressiveness, since it has become such a rarefied technological affair. Descriptions of the scientists who developed the Hiroshima bomb, and of the flying crew that delivered it, are almost completely devoid of any anti-Japanese aggressive feelings. And yet, at some other level, some of the people in such a system must imagine the horrible consequences of an atomic attack, must welcome this result and seek to intensify it. And isn't that aggressive imagery?

*Loyalty to Clan or Country or Church*. Arthur Koestler, among others, has argued that war is not due to an excess of aggressiveness but to an excess of loyalty. In his essay on *The Moral Equivalent of War* William James allowed for both. It does seem plausible that the division of the world into "Us" and "Them" facilitates the planning and waging of wars. There are important distinctions between national loyalties and ideological affiliations. But organized ideological groups cannot wage sustained war unless they have control of a political entity such as a nation. So, these different sorts of loyalty can be considered together.

*Self-interest and the profit motive*. When I was a high school student, I learned, from not very radical teachers, that "oil" was a major motive behind World War I. Today, such economic determinism is treated as crass and naive. Still, no one would deny that the profit motive plays some role in stimulating the arms race, and in the international arms trade. And it seems certain that these two processes increase the likelihood and murderousness of war. Doesn't it follow that the profit motive is a causal factor to be investigated? To be sure, in communist countries the profit motive is nominally proscribed. But there may be some hidden forms of it that contribute to the causal picture.

*Institutional structure*. The existence of armies, armament industries, and war planning agencies means that there are powerful groups in all modern societies whose own futures depend on the conduct of arms races and the probability of war. Such agencies have a tendency to grow, in part because of their inner workings, and in part because of external factors.

*Arms races*. There does seem to be agreement that arms races themselves make for war. The pattern of escalation inherent in technological progress is intensified by the military's perception of a need to anticipate and respond to the next step that the probable enemy may take. In modern weaponry reaction time and delivery time get shorter and shorter, while destructive power grows ever greater. This combination makes for the hair-trigger mentality that shoots down civilian aircraft and keeps us always on the brink.

A better understanding of how escalation processes work might help to make them less intense and less dangerous. Or if that is an impossible goal, we should know it and look for another way out. Strangely, in our studies of creative work, we deal with escalation processes that may account for breakthroughs; peace research and creativity research may have something to teach each other (see Wallace and Gruber 1989).

*Arms trade*. Most of this essay, like most peace research, has as its main concern superpower confrontation. But the international arms trade is both a by-product of the arms race and a stimulus for it. As the balance of forces evolves and as nuclear proliferation continues, we may find that we are focusing our attention on preventing the wrong war.

In the nineteenth century there was an international movement to abolish the slave trade and to abolish slavery. It was, by and large, successful. Slavery in the United States and serfdom in Czarist Russia were abolished at the same time. The international arms trade functions as a sort of slavery, forcing countries to buy what "they" (some potential enemy) have bought, perpetuating poverty, and increasing the danger of war. There is as yet no international movement to abolish the arms trade.

*Accident*. For epistemological reasons, one hesitates to include "accident" in a list of causes. Nevertheless, there is widespread concern that under conditions of long-continued international tension and arms racing, a nuclear war that no national leadership wants may be triggered by some random combination of circumstances.

*Qualification*. One notable exception to the peace researchers' neglect of the causes of wars is Morton Deutsch's article *The Prevention of World War III: A Psychological Perspective* (1983). In spite of the title, most of the essay is devoted to describing "the malignant social process" that perpetuates the arms race and increases the chances of nuclear war. His diagnosis amounts to a multi-factor theory of the causes of war. Although his analysis is very searching, he does not mention three of the issues I have raised above: aggressiveness, loyalties, and self-interest and the profit motive.

*Research Needs*. Although it is often repeated that "wars begin in the minds of men," psychologists have contributed relatively little to the examination of the causes of wars. It has seemed possible to examine ways of preventing wars without examining their causes. Rather than specify any particular research need, let us just say that it is time to end this anomalous situation.

## THE INVENTOR'S PARADIGM

The peace research community needs more discussion of its research paradigms. Such discussion should be open minded, exploratory, and friendly. We have to remember that we are all failures: the arms race goes on, the nuclear threat remains unbearable, and there are always wars in the world. We are looking for ways of doing something we don't know how to do. Remember, the task is not just research, but research that makes a difference.

In a tentative spirit then, I offer one candidate for a change in approach, the "Inventor's Paradigm." In violation of criteria I discuss below, I have not given it a complete trial. Although I have had some relevant experiences, and have thought about them in a new way in the course of writing this essay, space and time do not permit an account of them here. As a result, what follows remains a speculative suggestion.

The underlying idea behind the Inventor's Paradigm is the premise that truly moral conduct in difficult situations requires creative effort. Of course, there is something we call morality that presents little or no difficulty. But the interesting cases arise when there are intractable dilemmas and seemingly unsolvable problems. At such points we call into play the following line of reasoning: (1) all "ought" statements imply "can." There is no point in saying that something ought to be done if it is impossible. Ought is a subset of the possible. (2) Since we have specified that we are talking about difficult situations, we have no way of knowing what can be done unless we try as hard as possible. (3) But trying hard in the face of seemingly unsolvable problems means being as creative as possible. Therefore, "ought" implies "can" implies "create."

The idea that moral beings have an obligation to be creative has led me to the conclusion that some peace researchers ought to try out the inventor's paradigm. Now I must try to persuade you of the same.

*Science and invention*. Studies of the scientific process—historical, philosophical, and psychological—have focused mainly on conceptual and empirical advances. The role of invention in creative scientific work is badly neglected. By invention I mean the conception and construction of a device or mechanism designed to accomplish a certain specified range of effects, or to create certain phenomena. Most definitions of invention would include the idea of usefulness although that is a broad enough concept to include scientific and aesthetic as well as narrowly practical uses. To qualify as an invention, the idea in question must be developed beyond the stage of a mere suggestion. It must be elaborated to the point where the main obstacles are overcome and there is some evidence that, if used, it really works.

*Examples from the history of science*. Newton invented the reflecting telescope. Faraday invented at least the prototype of an electric generator. Darwin's whole thinking was colored by the metaphor of Nature's "contrivances," and he saw artificial selection as an arrangement under human control for emulating nature's inventiveness. He also invented a few mechanical devices for use in his research. Even Einstein, who might seem to be the very image of the abstracted scientist, had some twenty patents to his credit for inventions worked out with different collaborators. These included a system of variable condensers to amplify voltage differences, a noiseless refrigerator, a hearing aid, and a photoelectric device for controlling photographic exposures. Some of his inventions were tangential to his main interests, others were more intimately connected with his major scientific work. The invention of vaccines, by Pasteur and others, began at a time when the immune system was very poorly understood, but without those inventions we could not have arrived at our present advanced state of knowledge. Freud and others may properly be said to have invented the psychoanalytic method.

*Examples from psychology*. Psychologists are constantly inventing. Experimental psychologists sometimes invent measuring instruments and other devices, but most psychologists' inventions are arrangements for facilitating behavior they want to study. Among a great wealth of examples I choose a few that have some relevance to peace research: Kuo (1930) raised kittens together with rodents, to study the development of killing behavior in cats (Result: cats raised with rodents do not kill them).

Axelrod's study of *The Evolution of Cooperation* (1984) entails a double invention for discovering the characteristics of the Prisoners' Dilemma game when it is played repeatedly within a defined group—in other words, where the strategy adopted at one time may come back to haunt the player later on. All participants were very high level experts. The first invention was Axelrod's idea of the iterated Prisoners' Dilemma Tournament. The second invention was Anatol Rapoport's discovery of the Tit-for-Tat strategy as the long run winner against every other strategy the other participants invented. The key idea of Tit-For-Tat is to be "nice" so long as the opponent is nice; and if the opponent is nasty, to retaliate minimally and then return to being nice. This low-key strategy sometimes lost in the short run, but had the greatest survival value. Another finding of some portent is that in an extended tournament, as some players are eliminated, the relative survival value of each strategy changes, mainly in the direction of discouraging overly aggressive play.

As compared with such laboratory studies and simulations, the work of Kurt Lewin and his collaborators often went in the direction of field studies, such as the Lewin, Lippitt and White study of patterns of aggressive behavior in authoritarian and democratic groups (1939). In a very natural setting, Sherif et al. (1961) showed how a shared project could lead to a sense of solidarity between previously hostile groups of children.

In some ways, then, the Inventor's Paradigm is nothing but an extension of well established experimental methods. But I am arguing for going further, for conceiving of the inventions in question as actual efforts to change some aspect of the real situation we confront, especially the threat of nuclear war. At the same time, I believe we can and should approach such tasks in a way that maintains our disciplinary position as scientists, that honors the label, *peace research*.

*Invention as Research*

To qualify as research within the Inventor's Paradigm, we might expect the enterprise to exhibit the following characteristics. (1) It aims explicitly and consciously at extending our idea of the possible. In this sense, the process of invention is itself research. (2) In the course of trying to introduce the innovation in a practical way, systematic attention is given to obstacles encountered. By studying the resistances to change, the problem under attack will be better understood. (3) The whole process does not stop with success or failure of the project. It includes reflexive study of the process with the aim of improving our conceptual grasp of the problem in its context.

The research report ensuing from such efforts would be somewhat different from more conventional studies. It would include a high quality narrative account of the process of invention. It would include an account of the attempt to introduce and disseminate the invention. And it would reflect on next steps to be taken, with special reference to probable changes in historical circumstances.

*Toward Complete Inventions*

To avoid lapsing into mere suggestions, or limiting this kind of work to the established practices of experimental research, it would be necessary to pay special attention to the end-phases. We would expect that the work be carried forward at least to the proposal point—a degree of maturity similar to what is asked for by a government patent office. The proposal could be tested (and revised if necessary) by submitting it to an actual agency that might execute it. Finally, attempts might be made to raise funds to pursue the project in its more expensive application phase. Of course, at some point the research process phases into application, and here is where some client must take over. And that is precisely why it is important to think about the potential client at the beginning.

*The scope of inventions*. In making this proposal I do not mean to suggest that one or another of us should set about "inventing peace." But we can perhaps agree that the issue of war and peace affects almost every corner of our societies. Just as there are many ways of affecting the functioning of any living system, there are many ways of slowing down or otherwise modifying the function of the war system. And there are many ways of fostering peace. Some of these may be very modest, compared to the outcome we hope for.

## CONCLUSION

I recently reread Jean Giraudoux's play, *La guerre de Troie n'aura pas lieu*. The war is fated. The Greeks have sailed to Troy to take back Helen, who has been quite willingly kidnapped by Paris. The two warrior-statesmen, the Trojan Hector and the Greek Ulysses, agree to try to outwit fate and to keep peace. Circumstances are favorable for their policy agreement: they are war weary, they do not care very much about what happens to Helen, and other characters close to them are against the impending war.

But other citizens of Troy interfere. They reject the face-saving solution Hector and Ulysses have worked out. They initiate violent actions, and the war begins: it is not enough to reach the minds of the people if the policy makers are adamant. But in a prolonged encounter between complex societies, it is not enough to reach a few policy makers, no matter how highly placed they may be. That is why we need a wide-ranging peace research program and many inventions, great and small.

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# Subject Index

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