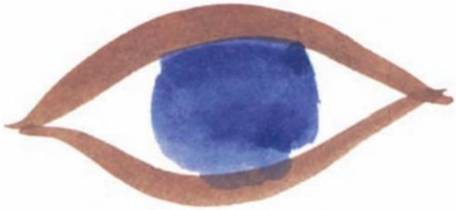
"Timely, wide-reaching and in many ways brilliant. . . . [Gardner's] effort to bring together the data of neurology, exceptionality, development, and symbolic-cultural skills is not only heroic but makes extremely evocative reading."—*The New York Review of Books*

HOWARD GARDNER

Author of Multiple Intelligences



Frames of Mind

The Theory of Multiple Intelligences

With a New Introduction by the Author

Frames
of ind

The Theory of Multiple Intelligences

HOWARD GARDNER

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New York

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Typeset in 10.75 point New Caledonia

Library of Congress Cataloging-in-Publication Data
Gardner, Howard. Frames of mind.
Includes bibliographical references and index.
1. Intellect. I. Title.
BF431.G244 1983 153 83-70765
ISBN-13 978-0-465-02508-4 (cloth)
ISBN-10 0-465-02508-0 (cloth)
ISBN-13 978-0-465-02509-1 (paper)
ISBN-10 0-465-02509-9 (paper)
ISBN-13 978-0-465-02510-7 (second edition paper)
ISBN-10 0-465-02510-2 (second edition paper)

2011 paperback edition ISBN: 978-0-465-02433-9
2011 e-book ISBN: 978-0-465-02434-6

10 9 8 7 6 5 4 3 2 1

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PART III
IMPLICATIONS AND APPLICATIONS

MULTIPLE INTELLIGENCES

The First Thirty Years

In the years since I published *Frames of Mind,* I have often been asked how I first got the idea of—or for—the theory of multiple intelligences. Probably the most truthful answer is "I don't know." However, such an answer satisfies neither the questioner nor, to be frank, me. With the benefit of hindsight, I would mention several factors, some remote, some directly feeding into my discoveries:

As a young person I was a serious pianist and enthusiastically involved with other arts as well. When I began to study developmental and cognitive psychology in the middle 1960s, I was struck by the virtual absence of any mention of the arts in the key textbooks—in the face of numerous discussions of scientific thinking. An early professional goal was to find a place for the arts within academic psychology. I am still trying! In 1967 my continuing interest in the arts prompted me to become a founding member of Project Zero, a basic research group at the Harvard Graduate School of Education begun by a noted philosopher of art, Nelson Goodman. For twenty-eight years (1972–2000), I was the codirector of Project Zero, and I am happy to say that the organization has continued to thrive under new leadership.

As my doctoral studies were drawing to a close, I first encountered the writings of Norman Geschwind,[1] a notable behavioral neurologist. I was fascinated by Geschwind's descriptions of what happens to once-normal or -gifted individuals who have the misfortune of suffering from a stroke,

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This introduction replaces a previous introduction that appeared in earlier editions of this book.

tumor, wound, or some other form of traumatic brain damage. Often the symptoms run counter to intuition: for example, a patient who is alexic but not agraphic loses the ability to read words but can still decipher numbers, name objects, and write normally. Without having planned it that way, I ended up working for twenty years on a neuropsychological unit, trying to understand the organization of human abilities in the brain: how they develop, how they (sometimes) work together, and how they break down under pathological conditions.

I have always enjoyed writing, and by the time I began my postdoctoral work with Geschwind and his colleagues in 1971, I had already completed three books. My fourth book, *The Shattered Mind*,[2] published in 1975, chronicled what happens to individuals who suffer from different forms of brain damage. I documented how different parts of the brain are dominant for different cognitive functions. After I completed *The Shattered Mind*, I thought that I might write a book that describes the psychology of different human faculties—a modern (and hopefully more scientifically grounded) reformulation of phrenology. In 1976 I actually wrote an outline for a book with the tentative title *Kinds of Minds*. One could say that this book was never written—and indeed I had totally forgotten about it for many years. But one could also say that it eventually emerged silently from the file cabinet and transmogrified into *Frames of Mind*.

So much for the more remote causes of the theory.

In 1979, a group of researchers affiliated with the Harvard Graduate School of Education received a sizeable grant from a Dutch foundation, the Bernard van Leer Foundation. This grant was designed for a grandiose purpose, one proposed by the foundation. Members of the Project on Human Potential (as it came to be called) were commissioned to carry out scholarly work on the nature of human potential and how it could best be realized. (Thinking of the United States, I've sometimes quipped that the Project on Human Potential is more of a "West Coast" topic than an "East Coast" topic.) When the project's principal investigators carved out our respective projects, I received an inviting assignment: to write a book chronicling what had been established about human cognition through discoveries in the biological and behavioral sciences. And so was born the research program that ultimately led to the theory of multiple intelligences.

Support from the van Leer Foundation allowed me, with the aid of many valued colleagues, to carry out an extensive research program. I saw this grant as providing a once-in-a-lifetime gift: we had the opportunity to collate and synthesize what I and others had learned about the development of cognitive capacities in normal and gifted children as well as the breakdown of such capacities in individuals who suffered some form of pathology. To put it in terms of my daily calendar, I was seeking to synthesize what I had been learning *in the mornings* from my study of brain damage with what I was learning *in the afternoons* from my study of cognitive development. These latter studies actually investigated how young children mastered symbol use in seven different areas ranging from singing to drawing to story-telling.[3] My colleagues and I also combed the literature from brain study, genetics, anthropology, psychology, and other relevant fields in an effort to ascertain the optimal taxonomy of human intellectual capacities.

I can identify a number of crucial turning points in this investigation. I don't remember when it happened but at a certain moment, I decided to call these faculties "multiple intelligences" rather than "assorted abilities" or "sundry gifts." This seemingly minor lexical substitution proved very important; I am quite confident that if I had written a book called *Seven Talents* it would not have received the attention that *Frames of Mind* received. As my colleague David Feldman has pointed out,[4] the selection of the word *intelligence* propelled me into direct confrontation with the psychological establishment that has long cherished and continues to cherish IQ tests. However, I disagree with Feldman's claim that I was motivated by a desire to "slay IQ"; neither the documentary nor the mnemonic evidence indicates that I had much interest in such a confrontation.

A second crucial point was the creation of a *definition* of an intelligence and the identification of a *set of criteria* that define what is, and what is not, an intelligence. I can't pretend that the criteria were all established *a priori*; rather, there was a constant fitting and refitting of what I was learning about human abilities with how best to delineate and then apply what ultimately became eight discrete criteria. I feel that the definition and the criteria—as laid out in the opening chapters of this book—are among the most original parts of the work. Interestingly, neither has received much discussion in the literature, on the part of supporters or critics.

When drafting *Frames of Mind* I was writing as a psychologist, and to this day that remains my primary scholarly identification. Yet, given the mission of the van Leer Foundation and my affiliation with the Harvard Graduate School of Education, it was clear to me that I needed to say something about the educational implications of MI theory. And so, I conducted background research about schools and about education, more broadly defined; in the concluding chapters I speculated about some educational implications of the theory. This nod toward education turned out to be another crucial point because it was educators, rather than psychologists, who found the theory of most interest.

By 1981 I had drafted the book that you are now reading (hence the thirty years of the title); thereafter I revised. The main lines of the argument had become clear. I was claiming that all human beings possess not just a single intelligence (often called by psychologists "g" for general intelligence). Rather, as a species, we human beings are better described as having a set of relatively autonomous intelligences. Most lay and scholarly writings about intelligence focus on a combination of linguistic and logical intelligences—the particular intellectual strengths, I often maintain, of a law professor, and the territory spanned by most intelligence tests. However, a fuller appreciation of human cognitive capacities emerges if we take into account spatial, bodily-kinesthetic, musical, interpersonal, and intrapersonal intelligences (the list as of 1983). We all have these intelligences—that's what makes us human beings, cognitively speaking. Yet at any particular moment, individuals differ for both genetic and experiential reasons in their respective profiles of intellectual strengths and weaknesses. And so, drawing on the analogy of our era, I contend that we have not one general-purpose computer but rather a set of discrete computers—the multiple intelligences—that operate somewhat independently of one another. No intelligence is in and of itself artistic or nonartistic; rather, several intelligences can be put to aesthetic ends, if individuals so desire. (I am using my linguistic intelligence here, but scarcely in the manner of a novelist or poet.) No educational implications follow directly from this psychological theory. But if individuals differ in their intellectual profiles, it makes sense to take this fact into account in devising an educational system for individuals, groups, or even nations.

By the time that *Frames of Mind* appeared I had already published half a dozen books. Each had had a modestly positive reception and a reasonable sale. I did not expect anything different from *Frames of Mind*, a lengthy and (for a trade audience) somewhat technical book, filled with hundreds of references and devoid of illustrations. But within a few months after its publication, I realized that this book was different. Not that the reviews were that exuberant or the sales that monumental. Rather, there was genuine "buzz" about the book. I was invited to give many talks, and when

I showed up at a site, people had at least heard about the theory and were eager to learn more about it. I even received invitations from abroad to talk about the book. Echoing artist Andy Warhol, I sometimes quip that MI theory gave me my fifteen minutes of fame. While I have done a number of things in my professional life and written about a broad range of topics, I realize that I am likely always to be known as the "father of multiple intelligences" or, less palatably, as the "MI guru."

For the first decade following the publication of *Frames of Mind*, I had two primary connections to the theory. The first relation was that of a bemused observer. I was amazed at how many individuals claimed that they wanted to revise their educational practices in the light of MI theory. Within a year or so, I had already met with eight public school teachers from Indianapolis who would shortly begin the Key School (now the Key Learning Community), the first school in the world organized explicitly around MI theory. I began to receive a steady stream of communications asking or telling me how to use MI theory in various kinds of schools or for various populations, from gifted young people to those with severe learning difficulties. While I tried to be responsive to these communications (a somewhat more demanding exercise in the pre–e-mail era), I always maintained that I was a psychologist and not an educator. I did not presume to know how best to teach a class of young persons or run an elementary or secondary school or, for that matter, design a program in a children's museum or a science museum, let alone a method of selection or promotion for a corporation.

My second relation was as a director of research projects that grew out of MI theory. The most ambitious effort was Project Spectrum, a collaboration with Jie-Qi Chen, David Feldman, Mara Krechevsky, Janet Stork, Julie Viens, and others.[5] The goal of Project Spectrum was to create a set of measures whereby one could ascertain the intellectual profile of young children—preschoolers and those in the primary grades. We ended up devising fifteen separate tasks that were designed to assess the several intelligences in as natural a manner as possible. The team had a great deal of fun devising the Spectrum battery and using it with different populations. We also learned that creating assessments is a difficult task and one that requires an enormous investment of time, thought, and money. I decided, without saying so in so many words, that I did not want myself to be in the assessment business, though I was very pleased if others chose to create instruments in an effort to assess the various intelligences.[6]

In this context, I should add that instruments that purpose to assess intelligences need to focus on what subjects can actually accomplish, putatively given a specific intelligence or intelligences. Many "MI tests" actually assess preferences and are dependent on self-reports, neither of which is necessarily a reliable index of the strength of the intelligence(s) in question. But I don't mean to dismiss such MI assessments: much can be learned about how people conceive of themselves, and through comparisons of response patterns found among and across different groups of subjects.[7]

Let me mention two other research projects that grew out of the first wave of interest in MI theory. Working with Robert Sternberg, another psychologist-critic of standard views of intelligence, my colleagues and I created a middle school curriculum called Practical Intelligences for School.[8] Working with colleagues from the Educational Testing Service, my colleagues and I developed a set of curriculum-and-assessment instruments designed to document learning in three art forms—graphic arts, music, and literary expression.[9]

To my surprise and pleasure, interest in multiple intelligences survived the transition to the 1990s. By that time I was prepared to undertake several new activities, variously related to MI theory. The first was purely scholarly. Building on the notion of different kinds of intelligences, I carried out case studies of individuals who stood out, putatively, as remarkable in terms of their particular profile of intelligences. This line of work led to my books on creativity (*Creating Minds*),[10] leadership (*Leading Minds*),[11] and extraordinary achievement, more broadly (*Extraordinary Minds*).[12] You can see that I was getting a lot of mileage by injecting book titles with the term *mind*!

The second was an extension of the theory. In 1994–1995 I took a sabbatical and used part of that time to consider whether, as some had proposed, there was convincing evidence for the existence of new intelligences. I concluded that there was ample evidence for a naturalist intelligence (the ability to make consequential distinctions among organisms and entities in the natural world); and suggestive evidence as well for a possible existential intelligence ("the intelligence of big questions").[13] I also explored the relation between intelligences—which I construe as biopsychological potentials—and the various domains and disciplines that exist in various cultures. While intelligences may possess the same names as cultural activities, they are not the same thing: as one example, the performance of music entails several intelligences (among them bodily and interpersonal); as another example, individuals strong in spatial intelligences can pursue a range of careers and avocations (running the gamut from sculpture to surgery). What we know and how we parse the world may well reflect in part the intelligences with which our species has been endowed.

I also proposed three distinct uses of the term *intelligence*[14]:

- A property of all human beings (All of us possess these 8 or 9 intelligences)
- A dimension on which human beings differ (No two people—not even identical twins—possess exactly the same profile of intelligences)
- The way in which one carries out a task in virtue of one's goals ("Joe may have a lot of musical skill, but his interpretation of that Bach partita reflects little intelligence")

A third activity featured a more proactive relationship to the uses and interpretations of my theory. For the first decade after publication, I had been content simply to observe what others were doing and saying in the name of MI theory. But by the middle 1990s, I had noticed a number of misinterpretations of the theory. As one example, the concept of intelligences was often conflated with that of learning styles; in fact, an intelligence (the computing power of an individual's musical or spatial or interpersonal capacity) is not at all the same as a style (the way in which one allegedly approaches a range of tasks). As another example, I noted the frequent confounding of a human intelligence with a societal domain (e.g., musical intelligence being misleadingly equated with mastery of a certain musical genre or role). I had also learned of practices that I found offensive—for example, describing different racial or ethnic group in terms of their characteristic intellectual strengths and deficiencies. And so, for the first time, I began publicly to differentiate my "take" on MI from that of others who had learned about and tried to make use of the theory.[15] And I acquired considerable concern about the responsibilities that attend to individuals who put forth ideas that become well known. This heightened concern ultimately led me, and other colleagues, to an ambitious study of professional responsibility, which came to be known as the GoodWork Project.[16]

A final feature of this second 1990s phase entailed a more active involvement with educational reform. This involvement took both a practical and a scholarly form. On the practical level, my colleagues and I at

Harvard Project Zero began working with schools as they attempted to implement MI practices and other educational programs that we had developed, such as one focused on teaching for understanding and, more recently, applications emerging from the GoodWork Project. In 1995 we also launched a summer institute, which continues until today and attracts practitioners and scholars from around the world.[17]

On the scholarly side, I began to articulate my own educational philosophy. In particular, I focused on the importance in the precollegiate years of achieving understanding in the major disciplines—science, mathematics, history, and the arts. For a host of reasons, achieving such understanding proves quite challenging. Efforts to cover too much material lead to superficial recall and doom the achievement of genuine understanding. As has been documented in countries with effective educational systems, learners are more likely to achieve enhanced understanding if they (or we) probe deeply into a relatively small number of topics. And once the decision is made to "uncover" rather than "cover," it is possible to take advantage of our multiple intelligences. Put concretely, we can approach topics in a number of ways (often termed different "entry points" to the same topic), we can make use of analogies and comparisons drawn from a range of domains, and we can express the key notions or concepts in a number of different symbolic forms.[18]

In light of three decades of research and reflection, I can summarize the educational implications of MI theory quite crisply—the so-called elevator speech. An educator convinced of the relevance of MI theory should *individualize* and *pluralize.* By individualizing, I mean that the educator should know as much as possible about the intelligences profile of each student for whom he has responsibility; and, to the extent possible, the educator should teach and assess in ways that bring out that child's capacities. By pluralizing, I mean that the educator should decide on which topics, concepts, or ideas are of greatest importance, and should then present them in a variety of ways. Pluralization achieves two important goals: when a topic is taught in multiple ways, one reaches more students. Additionally, the multiple modes of delivery convey what it *means* to understand something well. When one has a thorough understanding of a topic, one can typically think of it in several ways, thereby making use of one's multiple intelligences. Conversely, if one is restricted to a single mode of conceptualization and presentation, one's own understanding (whether teacher or student) is likely to be tenuous.

This line of analysis has led to a perhaps surprising conclusion. Multiple intelligences should not—in and of itself—be an educational goal. Educational goals need to reflect one's own (individual or societal) values, and these values can never come simply or directly from a scientific theory. Once one reflects on one's educational values and states one's educational goals, however, the putative existence of our multiple intelligences can prove very helpful. And, in particular, if one's educational goals encompass disciplinary understanding, then it is possible to mobilize our several intelligences to help achieve that lofty goal—for example, by employing multiple modes of presentation and diverse forms of assessment.

Since the turn of the millennium, my relationship to MI theory has been less intimate. The infant and child that was MI theory is now a young adult: as a parent and grandparent, I know that it is best for the theory to make its own way, without excessive managing from its forbears. Nonetheless, I have continued to be involved in several ways.

First of all, when possible, I have continued to help out institutions that want to apply the idea of multiple intelligences. (And when not able to do so myself, I am fortunate enough to have a small cohort of MI colleagues to whom I can turn.) In addition to the Key Learning Community, I've had a long-standing relationship with the New City School in St. Louis, Missouri, an impressive middle school that has pioneered many MI applications and also featured the first MI library. In 2005 I was excited to learn of the Explorama at the Danfoss Universe Theme Park in southwestern Denmark. This facility, consisting of dozens of games and exercises, represents an optimal instantiation of MI ideas. Each of the displays mobilizes a distinct set of intelligences, and by predicting one's own performance profile, one can even assess one's own intrapersonal intelligence. I've also lent a hand, upon request, to any number of schools, libraries, museums, and workplaces that seek to base practices on MI ideas or materials.[19]

While MI interest first occurred in the United States, it soon spread to the corners of the globe. The ideas have been particularly pursued in Latin America, Scandinavia, Southern Europe, Australia, the Philippines, Korea, and China. Interest in England, France, Germany, Russia, and Japan has been less salient—though I have had a wonderful alliance for over a decade with the dedicated band that constitutes the MI Society of Japan. Taking note of these international trends, and energized by a symposium organized in 2006 by Branton Shearer, my colleagues Jie-Qi Chen, Mindy Kornhaber, Seana Moran, and I decided to sponsor a conference and edit a book on the theme "Multiple Intelligences Around the World." Published in 2009, the book features forty-two authors from fifteen countries, on five continents, each detailing experiences with MI ideas and practices. Of course, I take pride in the numerous ingenious ways in which these ideas have been used and adapted. As an inveterate social scientist, I've also been intrigued by the many (and not always consistent) ways in which the ideas have been understood, and have sought, when possible, to relate these applications to conditions in the particular country or region of the world.

As just one example, let me mention the case of China. Though I had visited China several times in the 1980s and even written a book about my experiences there, I was unprepared for the overwhelming interest in MI ideas in China. In 2004 a conference on MI featured 2,500 papers, and I learned that there were at least a hundred books on multiple intelligences in Chinese. Naturally, I was curious to understand the reasons. From a journalist I met in Shanghai, I received a wonderful answer. She said to me, "In America, when people hear about MI, they think of their child. She may not be good in math, or in music, but she has wonderful interpersonal intelligence, they declare. In China," she went on, "these are simply eight areas in which we want all our children to excel." When I returned to China six years later, I learned that a great many schools, particularly for young children, claim to be based on MI ideas. Again, I queried widely why this was the case. I received a surprising reply from one informant, who said, "If we had a psychologist in China who was pushing for progressive ideas in education, we would not need to quote the words or ideas of Howard Gardner. We don't. In the absence of such a person, mentioning you and your ideas is a good way to open up our rather rigid educational system."

A third activity in which I've been involved entails efforts to answer the most frequent critiques of MI theory. In 2006 anthologist Jeffrey Schaler put together a book called *Howard Gardner Under Fire*[20] and invited thirteen scholars to critique my work. By prior arrangement, only four of them wrote directly about MI theory, but several others criticized it in passing. In 2009, psychologist and assessment expert Branton Shearer published a collection called *MI at 25.*[21] Here a wide range of scholars—including linguist Noam Chomsky, psychologists Mihaly Csikszentmihalyi and Michael Posner, educators Deborah Meier and Linda Darling-Hammond, and political analyst Charles Murray—put forth their own assessments and criticisms of the theory. With respect both to the Schaler and Shearer volumes, I composed detailed responses to each of the critics. While few scholars—or, for that matter, nonscholars—cherish criticism, there is no doubt that I learned a good deal from having to grapple with this wide range of discussion. In recent years I have also authored and coauthored several direct responses to criticisms of the theory in psychological and educational journals.[22]

While it is not possible to detail these discussions—which encompass hundreds of pages—it may be useful to mention the kinds of criticisms that I take seriously, as opposed to those that are of little interest to me. I am very interested in discussions of the particular criteria that I've put forth, and the extent to which particular candidate intelligences do, or do not, meet these criteria. Analysis of the possible cultural biases in the list also interest me. Empirical evidence on the relationship, or lack of relationship, among different candidate intelligences is central to my concerns. And of course, I'd like to know how constant or changing are an individual's configuration of intelligences over the course of a lifetime.

However, I am not engaged by quarrels about the term *intelligence*, or the way that I define it; by efforts to restrict intelligence only to academic problem-solving skills; or by performances on instruments that do not sample intellectual abilities in an "intelligence-fair" way. Put concretely, I'm much more interested in measures of interpersonal intelligence that examine directly how a person works with a group of peers than in paper-and-pencil measures that involve selecting the correct answer out of a multiple-choice array.

In speaking of measurement, I touch on the issue about which psychologists interested in intelligence have spilled the most liquid or electronic ink. Having put forth the theory, they maintain, I should be required to test it and, on the basis of the results of those tests, either revise or scuttle the theory. In their view the fact that I've elected not to become a psychometrician is no defense! I can well understand their loyalty to their instrumentation and to their way of thinking. Moreover, as a scholar, I do monitor efforts by others to test the theory—taking particular pleasure, of course, in those empirical studies that support the general enterprise. I was also gratified that a team of researchers, led by Mindy Kornhaber, documented the positive experiences of forty-one American schools that were inspired by MI ideas.[23] At the same time, however, I must stress that I've never felt that MI theory was one that could be subjected to an "up and down" kind of test, or even series of tests. Rather, it is and has always been fundamentally a work of synthesis; and its overall fate will be determined by the comprehensiveness of the synthesis, on the one hand, and its utility to both scholars and practitioners, on the other.

The reader may have noted that I've not mentioned changes in the theory itself, along the lines that occurred in the first ten or fifteen years after the publication of *Frames of Mind.* In fact, the theory has remained relatively constant in the past decade. I've considered the possibility of an additional intelligence—pedagogical intelligence, or the ability to teach others—but have not done the systematic study needed before its addition to The List. I've collaborated on various reviews and updates of the theory, including a definitive up-to-date summary of the theory, with Katie Davis, Scott Seider, and Joanna Christodoulou.[24] But my own scholarly interests have moved in new directions. It is probably the case that significant revisions of the theory will need to be undertaken by persons other than myself.

As already noted, my major scholarly work since the middle 1990s, the GoodWork Project, has focused on how professionals act responsibly. Though the work was stimulated in part by misapplications of MI theory, it has had a relatively independent life. On a trip to Manila in 2005, I was quite moved to learn that Mary Joy Abaquin, founder of an MI school, had succeeded in wedding my two interests. Since that time, Mary Joy has presented awards each year to individuals who are outstanding in one or more of the intelligences, while at the same time putting those intelligences to use in the service of the wider community. Few things could make a scholar more pleased than the discovery that someone has been able to effect a powerful relationship—and for that matter, a practical one—between two major lines of work, each of which he has pursued for decades.

This, then, is how the first decades of multiple intelligences look to me. I am grateful to the many individuals who have taken an interest in the theory—both within my research group and across the country and the globe. I have tried to be responsive to their inquiries and to build on what they have taught me. And I have come to realize that once one releases an idea—a "meme"—into the world, one cannot completely control its behavior, anymore than one can control those products of our genes called children. Put succinctly, MI has and will have a life of its own, over and above what I might wish for it, my most widely known intellectual offspring.

I've already indicated that the future of MI theory lies primarily in the minds—and the hands—of individuals other than myself. Still, it may be appropriate for me to step back, for a moment, and consider what lines of work might be undertaken by interested parties.

To begin with, there will be efforts to propose new intelligences. In recent years, in addition to the explosion of interest in emotional intelligences, there have been serious efforts to describe a spiritual intelligence and a sexual intelligence. My colleague Antonio Battro[25] has proposed the existence of a digital intelligence and has indicated how it may fulfill the criteria that I have set forth. The noted cognitive neuroscientist Michael Posner has challenged me to consider "attention" as a kind of intelligence.[26] I've also mentioned my own recent interest in the possibility of a pedagogical intelligence.

I have always conceded that in the end, the decision about what counts as an intelligence is a judgment call—not an unambiguous determination following the rigorous application of an algorithm. So far, I am sticking to my 8½ intelligences, but I can readily foresee a time when the list could grow, or when the boundaries among the intelligences might be reconfigured. For example, to the extent that the so-called Mozart effect gains credibility, one might want to rethink the relation between musical and spatial intelligences. Other hot spots might include whether logical and mathematical intelligences should be split up into separate intelligences, or whether other candidate intelligences—for example, dealing with healing or with spiritual matters—might be proposed in cultural groups with which I am not familiar.

Much work needs to be done on the question of how the intelligences can best be mobilized to achieve specific pedagogical goals. I do not believe that educational programs created under the aegis of MI theory lend themselves to the kinds of randomized control studies that the U.S. government is now calling for in education. But I do believe that well choreographed "design experiments" can reveal the kinds of educational endeavors where an MI perspective is appropriate and where it is not. To state just one example, I think that MI approaches are particularly useful when a student is trying to master a challenging new concept—say, gravity in physics, or the Zeitgeist in history. For a long time I was skeptical that MI ideas can be useful in mastering a foreign language—but I've been impressed by the numerous teachers of foreign languages who claim success using MI approaches for both motivational and conceptual purposes. Also, I think that the potential of MI ways of thinking for dealing with various kinds of learning problems has hardly been scratched. I am enormously enthusiastic about the efforts of David Rose, my valued colleague, and others at his organization cast.org, to create curricula that can address the full range of learners. As Rose puts it, we should not think of students as disabled; we should instead consider whether our curricula may be disabled.

Were I personally granted more time and energy to explore the ramifications of MI theory, I would devote those precious gifts to two endeavors. First of all, as indicated above, I have become increasingly fascinated by the ways in which societal activities and domains of knowledge emerge and become periodically reconfigured. Any complex society has 100–200 distinct occupations at the least; and any university of size offers at least fifty different areas of study. Surely these domains and disciplines are not accidents, nor are the ways that they evolve and combine simply random events. The culturally constructed spheres of knowledge must bear some kind of relation to the kinds of brains and minds that human beings have, and the ways that those brains and minds grow and develop in different cultural settings. Put concretely, how does human logical-mathematical intelligence relate to the various sciences, mathematics, and computing software and hardware that have emerged in the past few thousand years, and those that may emerge one year or a hundred years from now? Which makes which, or, more probably, how does each shape the other? Will computers augment or even substitute for particular intelligences or combinations of intelligences? How does the human mind deal with interdisciplinary studies—are they natural or unnatural cognitive activities? Or to be a bit wild, what would MI perspectives reveal about dogs or birds or other primates? Or, for that matter, robots or smart machines? I would love to be able to think about these issues in a systematic way.

Second, from the start, one of the appealing aspects of MI theory was its reliance on biological evidence. In the early 1980s there was little relevant evidence from genetics or evolutionary psychology; such speculations were mere handwaving. There was, however, powerful evidence from the study of neuropsychology for the existence of different mental faculties; and—whatever new details may emerge—that evidence constituted the strongest leg on which to justify MI theory.

Of course, knowledge has accumulated at a phenomenal rate in both brain science and genetics. At the risk of seeming hyperbolic, I am prepared to defend the proposition that we have learned as much from 1981 to 2011 as we did in the previous 500 years. As an amateur geneticist and neuroscientist, I have tried as best I can to keep up with the cascade of new findings from these areas. I can say with some confidence that no findings have radically called into question the major lines of MI theory. But I can say with equal confidence that, in light of the findings of the past three decades, the biological basis of MI theory needs urgently to be brought up to date.

At the time that MI theory was introduced, it was very important to make the case that human brains and human minds are highly differentiated entities. It is fundamentally misleading to think about a single mind, a single intelligence, a single problem-solving capacity. As an acquaintance recently remarked, exposure to the idea of multiple intelligences made her see in Technicolor what had previously appeared to be only in black and white! And so, along with many others, I tried to make the argument that the mind/brain consists of many modules/organs/intelligences, each of which operates according to its own rules in relative autonomy from the others.

Happily, nowadays the argument for modularity is largely established. Even those who believe strongly in general intelligence and across-the-board skills feel the need to defend their position, in a way that was unnecessary in decades past. But it is time to revisit the issue of the relationship between general and particular intelligences. This revisiting can and is being done in various intriguing ways. Psychologist Robbie Case proposed the notion of central conceptual structures—broader than specific intelligences but not as all-encompassing as Piagetian general intelligence.[27] Philosopher Jerry Fodor contrasts impenetrable dedicated modules with a permeable central system.[28] The team of Marc Hauser, Noam Chomsky, and Tecumseh Fitch suggests that the unique quality of human cognition is its capacity for recursive thinking; perhaps it is recursion that characterizes advanced thinking in language, number, music, social relations, and other realms.[29] Electrophysiological and radiological studies indicate that various brain modules may already be activated in newborns. Neural imaging studies of individuals solving IQ-style problems suggest that certain areas of the brain are most likely to be drawn on for these kinds of problems; and there may be evidence for genes that contribute to unusually high IQ, as there clearly are genes that cause retardation. Indeed, our own case studies of unusually high performances suggests a distinction between those who (like musicians or mathematicians) are outstanding in one area, as opposed to those generalists (politicians or business leaders) who display a relatively flat profile of cognitive strengths. I think it would be worthwhile to study in detail the differences between those who deploy a focused *laser* intelligence and those who display an ever-vigilant and shifting *searchlight* intelligence.

Were I granted another lifetime or two, I would like to rethink the nature of intelligence with respect to our new biological knowledge, on the one hand, and our most sophisticated understanding of the terrain of knowledge and societal practice, on the other—another Project on Human Potential, perhaps! I don't expect this wish to be granted. But I am glad to have had the chance to make an opening move some thirty years ago, to have been able to revisit the gameboard periodically, to get to know and to work with wonderful colleagues in many corners of the globe, and to lay out this problematic so that other interested players can have their chance to engage.

Note: For their useful comments on earlier drafts of this introduction, I thank Jie-Qi Chen, Katie Davis, Mindy Kornhaber, Scott Seider, and Ellen Winner.

Howard Gardner
November 2010

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INTRODUCTION TO THE TENTH-ANNIVERSARY EDITION, 1993

In his dreams, every author envisions a wonderful career for the book on which he is working. Still, while writing *Frames of Mind*, I did not anticipate that the book would find a receptive audience in so many circles across so many lands. And I certainly did not expect to have the privilege of introducing a tenth-anniversary edition of the book.

While working on *Frames of Mind*, I viewed it principally as a contribution to my own discipline of developmental psychology and, more broadly, to the behavioral and cognitive sciences. I wanted to broaden conceptions of intelligence to include not only the results of paper-and-pencil tests but also knowledge of the human brain and sensitivity to the diversity of human cultures. Although I discussed the educational implications of the theory in the closing chapters, my eyes were not beamed toward the classroom. In fact, however, the book has exerted considerable influence in educational quarters: my colleagues and I at Harvard Project Zero have undertaken several educational experiments inspired by "MI theory," and there have been numerous other attempts to apply the theory to particular educational environments. In the companion volume to this book—*Multiple Intelligences: The Theory in Practice* (Gardner 1993)—I review the principal ways in which the theory has entered into contemporary educational discourse.

Here, in this new introduction to *Frames of Mind* (which incorporates portions of the introduction to its first paperback edition in 1985), I have five aims: to summarize the principal themes of *Frames of Mind*; to situate MI theory within the history of studies of intelligence; to relate *Frames of Mind* to my more recent work; to respond to some of the principal criticisms leveled at MI theory; and to forecast possible future work. At the end of this introduction are bibliographical references for materials that are not treated further in the book itself.

The Principal Themes of *Frames of Mind*

At the time I wrote *Frames of Mind*, I had not fully anticipated the extent to which most people continued to adhere to two assumptions about intelligence: first, that it is a single, general capacity that every human being possesses to a greater or lesser extent; and that, however defined, it can be measured by standardized verbal instruments, such as short-answer, paper-and-pencil tests. In an effort to help new readers to enter the work, and to forestall these widely held but ultimately untenable conceptions, I ask you to perform two thought experiments.

First of all, try to forget that you have ever heard of the concept of intelligence as a single property of the human mind, or of that instrument called the intelligence test, which purports to measure intelligence once and for all. Second of all, cast your mind widely about the world and think of all the roles or "end states"—vocational and avocational—that have been prized by cultures during various eras. Consider, for example, hunters, fishermen, farmers, shamans, religious leaders, psychiatrists, military leaders, civil leaders, athletes, artists, musicians, poets, parents, and scientists. Honing in closer, then, consider the three end states with which I begin *Frames of Mind*: the Puluwat sailor, the Koranic student, and the Parisian composer at her microcomputer.

In my view, if we are to encompass adequately the realm of human cognition, it is necessary to include a far wider and more universal set of competences than we have ordinarily considered. And it is necessary to remain open to the possibility that many—if not most—of these competences do not lend themselves to measurement by standard verbal methods, which rely heavily on a blend of logical and linguistic abilities.

With such considerations in mind, I have formulated a definition of what I call an "intelligence." An intelligence is the ability to solve problems, or to create products, that are valued within one or more cultural settings—a definition that says nothing about either the sources of these abilities or the proper means of "testing" them.

Building upon this definition, and drawing especially on biological and anthropological evidence, I then introduce eight distinct criteria for an intelligence. As set forth in Chapter 4, these criteria range from the isolation of a capacity as a result of brain damage to the susceptibility of a capacity to encoding in a symbolic system. Then, in Part II of the book, I describe in detail each of the seven candidate intelligences: the linguistic and logical-mathematical intelligences that are at such a premium in schools today; musical intelligence; spatial intelligence; bodily-kinesthetic intelligence; and two forms of personal intelligence, one directed toward other persons, one directed toward oneself.

Following the introduction of the intelligences and a description of their respective modes of operations, I present a critique of the theory in terms of those deficiencies most evident to me at the time of writing. I conclude with some considerations of how intelligences do—and can—develop within a culture, and of how they can be mobilized in various educational settings.

When one puts forth a new theory, it is sometimes helpful to indicate the perspectives to which it is most radically opposed. This tack seems especially important in light of the critics who have been unable—or unwilling—to abandon these traditional perspectives. I introduce two exhibits in this regard. First, an advertisement for an intelligence test begins:

> Need an individual test which quickly provides a stable and reliable estimate of intelligence in 4 or 5 minutes per form? Has three forms? Does not depend on verbal production or subjective scoring? Can be used with the severely physically handicapped (even paralyzed) if they can signal yes–no? Handles two-year-olds and superior adults within the same short series of times and the same format?

and continues in this vein. Whatever might be the value of this test, I can state unequivocally that the description of it implies an illusory wonderland of testing. Furthermore, I am equally suspicious of claims to test intelligence (whatever it might be) by means of reaction-time measures or brain waves. That these measures may well correlate with IQs is, from my perspective, all the more reason for calling IQs into question.

My second exhibit comes from a more venerable source—a well-known quotation from Samuel Johnson. The redoubtable doctor once defined "true genius" as "a mind of large general powers, accidentally determined to some particular direction." While I do not question that some people may have the potential to excel in more than one sphere, I strongly challenge the notion of large general powers. To my way of thinking, the mind has the potential to deal with several different kinds of *content*, but a person's facility with one content has little predictive power over his or her facility with other kinds. In other words, genius (and, *a fortiori*, ordinary performance) is likely to be specific to particular contents: human beings have evolved to exhibit several intelligences and not to draw variously on one flexible intelligence.

Studies of Intelligence

As I attempt to situate my own work within the broader history of efforts to conceptualize intelligence, I find it useful to divide the historical continuum into loosely sequential phases: lay theories, the standard psychometric approach, and pluralization and hierarchization.

Lay Theories. For most of human history, there was no scientific definition of intelligence. No doubt people spoke often enough about the concept of intelligence and labeled others as more or less "bright," "dull," "clever," or "intelligent." Outstanding figures as diverse as Thomas Jefferson, Jane Austen, Frederick Douglass, and Mahatma Gandhi could all be called "smart." Such informal discussion sufficed in ordinary parlance, but chiefly because people rarely challenged one another on just what was meant by intelligent.

The Standard Psychometric Approach. Just about a century ago, psychologists made the first efforts to define intelligence technically and to devise tests that would measure it (see the opening pages of Chapter 2). In many ways, these efforts represented an advance and a singular success for scientific psychology. Nonetheless, in light of factors for which the pioneers cannot be blamed, there has been considerable abuse of "IQ testing" on the streets and surprisingly little theoretical advance within the psychometric community proper (Gould 1981).

Pluralization and Hierarchization. The first generation of psychologists of intelligence, such as Charles Spearman (1927) and Lewis Terman (1975), tended to believe that intelligence was best conceptualized as a single general capacity for conceptualization and problem solving. They sought to demonstrate that a group of scores on tests reflected a single underlying factor of "general intelligence." It was probably inevitable that this contention would be challenged; and, over the years, such psychologists as L. L. Thurstone (1960) and J. P. Guilford (1967) argued for the existence of a number of factors, or components, of intelligence. In the broadest sense, *Frames of Mind* is a contribution to this tradition, although it differs principally in the sources of evidence on which it relies. Whereas most pluralists defend their position by stressing the low correlations among groups of tests, I have based MI theory on neurological, evolutionary, and cross-cultural evidence.

Having posited several components of intelligence, one must then question how and whether they relate to one another. Some scholars, such as Raymond Cattell (1971) and Philip Vernon (1971), argue for a hierarchical relationship among factors, seeing general, verbal, or numerical intelligence as presiding over more specific components. Other scholars, such as Thurstone, however, resist the urge to create a hierarchy of factors, and claim that each should be considered as an equivalent member of a heterarchical structure. These three phases take us up to the publication of *Frames of Mind* in 1983. In the subsequent decade, I discern at least two new trends: contextualization and distribution.

Contextualization. Reflecting a general trend within the behavioral sciences, researchers have become increasingly critical of psychological theories that ignore crucial differences among the contexts within which human beings live and develop. Being a human being in a contemporary postindustrial society is an entirely different matter from being a human being during the Neolithic or the Homeric eras, or, for that matter, from being one who lives in a preliterate or a Third World setting today. Rather than assuming that one would possess a certain "intelligence" independent of the culture in which one happens to live, many scientists now see intelligence as an interaction between, on the one hand, certain proclivities and potentials and, on the other, the opportunities and constraints that characterize a particular cultural setting. According to the influential theory of Robert Sternberg (1985), part of intelligence is one's sensitivity to the varying contents around one. In more radical formulations inspired by the work of the Soviet psychologist Lev Vygotsky (1978), some researchers investigate differences among cultures and their practices, rather than differences among individuals (Lave 1988).

Distribution. Although the idea of distribution echoes that of contextualization, a "distributed view" focuses on the relation of the person to the things/objects in the immediate environment, rather than on the strictures and values of the larger culture or context. On the traditional "individual-centered" view adhered to in the first three phases of intelligence theory, one's intelligence is carried within one's head; in principle, that intelligence could be measured in isolation. According to the distributed view, however, one's intelligence inheres as much in the artifacts and individuals that surround one as in one's own skull. My intelligence does not stop at my skin; rather, it encompasses my tools (paper, pencil, computer), my notational memory (contained in files, notebooks, journals), and my network of associates (office mates, professional colleagues, others whom I can phone or to whom I can dispatch electronic messages). A forthcoming book, entitled *Distributed Cognition*, sets forth the principal principles of a distributed view (Salomon, in press); see also the useful book *Perspectives on Socially Shared Cognition,* authored by Lauren Resnick and her colleagues (1991).

With the benefit of hindsight, I can point to hints of contextualization and distribution in the first edition of *Frames of Mind*. In presenting spatial intelligence, for example, I emphasized the extent to which the expression of that intelligence is determined by the opportunities afforded in various cultures (ranging from sailing to architecture to geometry to chess), and also the value of various tools and notations in enhancing the intelligences of the growing child. Yet, I think it fair to say that in 1983 I centered the multiple intelligences far more within the skull of the single individual in 1983 than I would one decade later.

Will intelligence continue to move beyond the brain of the individual into the realm of the artifacts and contexts of the wider culture? A large part of the research community, and particularly that influenced by trends on the European continent or in Asia, would respond "yes." From that perspective, the exclusive focus of intelligence on the skills and flexibility of the single individual reflects a peculiarly Anglo-American bias. But those who favor the standard psychometric approach to cognition or intelligence have by no means laid down their disputational weapons.

Indeed, in the past decade, there have been renewed efforts to support the traditional views of intelligence and its operation in intelligence tests. Scholars such as Arthur Jensen (1980) and Hans Eysenck (1981) have not only maintained their belief in the singularity of intelligence but also have supplemented their long-term loyalty to psychometric instruments with fresh enthusiasm about the brain-basis of intelligence. They now contend that intelligence reflects a basic property of the nervous system and can be assessed electrophysiologically, without recourse to paper-and-pencil instruments. A younger colleague, Michael Anderson (1988), has amassed evidence to suggest that such indices of intelligence can be ascertained even among infants. And perhaps most dramatically, Thomas Bouchard and his colleagues (1990) at the University of Minnesota have demonstrated a surprisingly high heritability of psychometric intelligence among a population uniquely situated to provide evidence on this topic: identical twins reared apart. To the extent that the Bouchard-Jensen-Eysenck position is correct, there is really no need to pay attention to cultures, contexts, or distributions of intelligence.

What is one to make of this situation, where one part of the "intelligence community" is moving further and further toward social and cultural accounts of intelligence while another part is amassing evidence of the neurological and genetic basis of intelligence? Can they both be right? I do not see these two research traditions as necessarily on a collision course. It could well be that a certain property of the nervous system—say, speed and flexibility of nerve conduction—is largely inborn and accounts in significant measure for eventual success on certain kinds of paper-and-pencil measures. So far as this is so, the "tough-minded" wing of intelligence studies will continue to be tenable. At the same time, it could well be that the forms in which intelligence is expressed outside a test situation, and that the ways in which human beings carry out roles in their culture, remain indefinitely and illuminatingly varied: here the "tender-minded" approach to intelligence studies will remain an important endeavor. A division of explanatory labor is also conceivable: in a recently published volume, Anderson (1992) stresses the power of the traditional view for illuminating infant cognition while invoking a multiple intelligences perspective for later development.

I anticipate, however, that the "tough" and the "tender" will continue to fight it out rather than merely agree to divide the intelligence terrain. For example, meeting psychometricians on their own ground, Stephen Ceci (1990) has shown the many ways in which even performance on the simplest kinds of reaction-time measures are subject to training and cultural effects. And, under the label of the "new environmentalism," my colleague Robert LeVine (1991) has challenged the inferences drawn from studies of twins reared apart but within the same American ambience. In his view, human environments can differ in a multitude of ways, leading to differences in performance far greater than those observed in twins raised in what are basically variations of a modern Western middle-class environment.

Frames of Mind and My Recent Work

As I have indicated, much of the work my colleagues and I have undertaken in the past decade has examined educational implications of MI theory (see Gardner 1993). In particular, we have sought to take into account the various differences in individual profiles of intelligences within an educational setting. Describing an "individual-centered school," we have addressed the ways in which each child's profile of intelligences can be assessed; the ways in which each child can be aligned with curriculum, particularly with reference to the way in which that curriculum is presented to the child; and the ways in which youngsters with particular profiles of intelligence can be matched up appropriately with educational opportunities outside the confines of school.

A great deal of our recent effort has been expended on the development of means of assessment that are "intelligence-fair": that allow a measurement of intellectual strengths without going through the "lenses" of language and logic, as is required in standard paper-and-pencil measures. At first, we thought it would be possible and desirable to try to measure an individual's intelligence in "pure form," yielding something akin to a seven-pronged intelligence profile. Increasingly, however, as we came to accept the contextualization and distribution perspectives, it seemed ill advised, and perhaps impossible, to attempt to measure "raw" intelligence.

As we now see it, intelligences are always expressed in the context of specific tasks, domains, and disciplines. There is no "pure" spatial intelligence: instead, there is spatial intelligence as expressed in a child's puzzle solutions, route finding, block building, or basketball passing. By the same token, adults do not exhibit their spatial intelligence directly but are more or less proficient chess players or artists or geometricians. Thus, we are well advised to assess intelligences by watching people who already are familiar with and have some skills in these pursuits, or by introducing individuals to such domains and observing how well one can move beyond the novice stage, with or without specific supports or scaffolding.

This shift in philosophy of assessment reflects what is probably the most important conceptual advance in MI theory: the distinction among *intelligences*, *domains*, and *fields*. In the original formulation, these distinctions were not properly drawn, leading to confusion among readers and, not infrequently, within my own thinking. But collaborative work with David Feldman (1980, 1986) and Mihaly Csikszentmihalyi (1988) has provided me with a well-founded taxonomy.

At the level of the individual, it is proper to speak about one or more human *intelligences*, or human intellectual proclivities, that are part of our birthright. These intelligences may be thought of in neurobiological terms. Human beings are born into cultures that house a large number of *domains*—disciplines, crafts, and other pursuits in which one can become enculturated and then be assessed in terms of the level of competence one has attained. While domains, of course, involve human beings, they can be thought of in an impersonal way—because the expertise in a domain can in principle be captured in a book, a computer program, or some other kind of artifact.

There is a relation between intelligences and domains, but it is crucial not to confound these two realms. A person with musical intelligence is likely to be attracted to, and to be successful in, the domain of music. But the domain of musical performance requires intelligences beyond the musical (for example, bodily-kinesthetic intelligence and the personal intelligences), just as musical intelligence can be mobilized for domains beyond music in the strict sense (as in dance or in advertising). More generally, nearly all domains require proficiency in a set of intelligences; and any intelligence can be mobilized for use in a wide array of culturally available domains.

During socialization, intercourse occurs principally between the individual and the domains of the culture. But once one achieves a certain competence, the *field* becomes very important. The field—a sociological construct—includes the people, institutions, award mechanisms, and so forth that render judgments about the qualities of individual performances. To the extent that one is judged competent by the field, one is likely to become a successful practitioner; on the other hand, should the field prove incapable of judging work, or should it judge the work as being deficient, then one's opportunity for achievement will be radically curtailed.

The trio of *intelligence*, *domain*, and *field* has proved not only useful for unraveling a host of issues raised by MI theory but also particularly fruitful for studies of creativity. As formulated originally by Csikszentmihalyi (1988), the felicitous question is: Where is creativity? The answer is that creativity should not be thought of as inhering principally in the brain, the mind, or the personality of a single individual. Rather, creativity should be thought of as emerging from the interactions of three nodes: the individual with his or her own profile of competences and values; the domains available for study and mastery within a culture; and the judgments rendered by the field that is deemed competent within a culture. To the extent that the field accepts innovation, one (or one's work) can be seen as creative; but to the extent that an innovation is rejected, or not understood, or considered not innovative, it is simply invalid to continue to maintain that a product is creative. Of course, in the future, the field may choose to alter its early judgments.

Each of the scholars who has worked on this formulation has put it to work distinctively. In my own case, I have defined the creative individual in ways paralleling my definition of intelligence. Specifically, the creative individual is one who *regularly* solves problems or fashions products in a *domain*, and whose work is considered both novel and acceptable by knowledgeable members of a field. On the basis of this definition, I have studied six men and one woman who early in this century were instrumental in formulating modern consciousness in the West. Each—Sigmund Freud, Albert Einstein, Igor Stravinsky, Pablo Picasso, T. S. Eliot, Martha Graham, and Mahatma Gandhi—exemplifies one of the seven intelligences (Gardner, in press).

Those interested in the evolution of the theory of multiple intelligences since 1983 often ask whether additional intelligences have been added—or original candidates deleted. The answer is that I have elected not to tamper for now with the original list, though I continue to think that some form of "spiritual intelligence" may well exist. It is pertinent to point out that my notions of "intrapersonal intelligence" have shifted somewhat in the past decade. In *Frames of Mind*, I stressed the extent to which intrapersonal intelligence grew out of, and was organized around, the "feeling life" of the individual. If I were to rework the relevant parts of Chapter 10 today, I would stress instead the importance of having a viable model of oneself and of being able to draw effectively upon that model in making decisions about one's life.

In addition to work on the educational implications of MI theory, and the extension of that work to the realm of creativity, I have been involved in one other line of study that grows out of MI theory. The positing of different intelligences implies two further considerations: Why do human beings possess particular intelligences, and what are the factors that lead intelligences to develop as they do?

Both of these issues lie near the heart of developmental psychology, the discipline in which I was trained. And, as it happens, my own work on intelligence can be seen as part of a general trend in that discipline to consider the different domains or "modules of the mind" (Carey and Gelman 1991; Fodor 1983; Keil 1989). One result of this ongoing research has been the effort to delineate the different *constraints* at work in the realms of the mind: for example, to indicate the kinds of assumption infants make about the realm of number or causality, the strategies toddlers naturally invoke in learning natural language, the sorts of concepts children easily form as opposed to those that are almost impossible to form.

"Constraints" research has revealed that by the end of early childhood, youngsters have developed powerful and already entrenched theories about their immediate worlds: the world of physical objects and forces; the world of living entities; the world of human beings, including their minds. Surprisingly, and in contradiction to the claims of the great developmentalist Jean Piaget (Mussen and Kessen 1983), these naïve "conceptions" and "theories" prove difficult to alter, despite years of schooling. And so it often happens that the "mind of the five-year-old" ends up unaffected by the experiences of school. In *The Unschooled Mind* (1991), I illustrate the power of these constraints by showing that in every area of the curriculum, the mind of the five-year-old continues to hold sway.

Taken together, the work on multiple intelligences and the work on the constraints of the mind yield a view of the human being significantly different from the one generally subscribed to a generation ago. In the heyday of the psychometric and behaviorist eras, it was generally believed that intelligence was a single entity that was inherited, and that human beings—initially a blank slate—could be trained to learn anything, provided that it was presented in an appropriate way. Nowadays an increasing number of researchers believe precisely the opposite: that there exists a multitude of intelligences, quite independent of each other; that each intelligence has its own strengths and constraints; that the mind is far from unencumbered at birth; and that it is unexpectedly difficult to teach things that go against early "naïve" theories or that challenge the natural lines of force within an intelligence and its matching domains.

At first blush, this diagnosis would appear to sound a death knell for formal education. It is hard enough to teach to one intelligence; what about seven? It is hard enough to teach even when anything can be taught; what to do if there are distinct limits and strong constraints on human cognition and learning?

In truth, however, psychology does not directly dictate education (Egan 1983); it merely helps one to understand the conditions within which education takes place. One person's limitation can be another person's opportunity. Seven kinds of intelligence would allow seven ways to teach, rather than one. And any powerful constraints that exist in the mind can be mobilized to introduce a particular concept (or a whole system of thinking) in a way that children are most likely to learn it and least likely to distort it. Paradoxically, constraints can be suggestive and ultimately freeing.

Criticisms of MI Theory

In the course of a decade of discussion, there have been numerous criticisms of MI theory and numerous opportunities for me to attempt to respond to them. Because some of these criticisms and responses are anticipated in Chapter 11 and discussed in *Multiple Intelligences: The Theory in Practice*, I shall here focus on what I believe to be the most important issues: terminology, correlation among intelligences, intelligences and styles, the processes of intelligences, and the risks of repeating the sins of intelligence testing.

Terminology. Many individuals, though happy to recognize the existence of different abilities and faculties, balk at the use of the word *intelligence*. "Talents are fine," they say, "but intelligence should be reserved for more general kinds of capacities." One can, of course, define words in any way one likes. In delineating a narrow definition of intelligence, however, one usually devalues those capacities that are not within that definition's purview: thus, dancers or chess players may be talented but they are not smart. In my view, it is fine to call music or spatial ability a talent, so long as one calls language or logic a talent as well. But I balk at the unwarranted assumption that certain human abilities can be arbitrarily singled out as qualifying as intelligence while others cannot.

Correlation Among Intelligences. Several critics have reminded me that there are generally positive correlations (the so-called positive manifold) among tests for different faculties (for example, space and language). More generally, within psychology, almost every test of abilities correlates at least a little bit with other tests of ability. This state of affairs gives comfort to those who would posit the existence of "general intelligence."

I cannot accept these correlations at face value. Nearly all current tests are so devised as to call principally on linguistic and logical faculties. Often the very wording of the question can tip off the test takers. Accordingly, a person with the skills important for success on such instruments is likely to do relatively well even in tests of musical or spatial abilities, while one who is not especially facile linguistically or logically is likely to be impaired on such standard tests, even if one has skills in the areas that are allegedly being tested.

The truth is that we do not yet know how far various intelligences (or, as I would now say, instantiations of various intelligences) actually correlate. We do not know whether someone who has the intelligences to be a good chess player or architect also has the intelligences to succeed in music or mathematics or rhetoric. And we will not know until we have devised means of assessment that are intelligence-fair. At such a time, we may well find certain correlations among intelligences, and such findings would naturally result in a redrawing of the map of human cognition. I would be very surprised, however, if most of the intelligences I have defined in this book were to disappear in the new cartography—but far less so at the emergence of new intelligences or sub-intelligences.

Intelligences and Styles. Many individuals have pointed out that my list of intelligences resembles lists put out by researchers interested in learning styles, working styles, personality styles, human archetypes, and the like; and asked what is new in my formulation. Without question, there will be overlap between these lists, and I may well be trying to get at some of the same dimensions as those in the "styles" world. Still, three aspects of my theory are indeed distinctive.

First of all, I arrived at the seven intelligences by a method I believe to be unique: the synthesis of significant bodies of scientific evidence about development, breakdown, brain organization, evolution, and other kindred concepts (see Chapter 4). Most other lists are a consequence either of the correlations among test scores or of empirical observations—for example, of students in school.

Second, my intelligences are specifically linked to content. I claim that human beings have particular intelligences because of informational contents that exist in the world—numerical information, spatial information, information about other people. Most stylistic accounts are assumed to cut across content: thus, one is said to be impulsive or analytic or emotive "across the board."

Third, rather than being analogous to (or even redundant with) styles, intelligences may well need to cross-cut other kinds of analytic categories. Perhaps styles are intelligence-specific, or intelligences are style-specific. There is, in fact, empirical evidence on this issue. In our educational effort with young children called Project Spectrum (Gardner and Viens 1990), we have found that certain "working styles" prove to be quite content-specific. The same child who is reflective or engaged with one content can turn out to be impulsive or inattentive with another content. Just why this occurs we do not know; but it cautions against an easy assumption that styles are independent of content, or that intelligences can be collapsed with styles.

The Processes of Intelligences. Several sympathetic critics did not question the existence of several intelligences but criticized me for being purely descriptive. From their vantage point, it is the job of the psychologist to lay out the processes whereby mental activity is carried out.

I concede that the work in *Frames of Mind* is largely descriptive. I believe that such description is an appropriate place to begin—to make the case for a plurality of intelligences. Certainly nothing in the work in any way blocks the path toward an exploration of the processes whereby the intelligences operate; and indeed, at various points in this volume, I offer suggestions about what processes and operations might be entailed in spatial, musical, and other intelligences.

It is perhaps worth mentioning that, at the time *Frames* was published, most psychologists believed that human information processing was best explained by the serial von Neumann computer. Within a few years, that allegiance had completely changed, and the so-called parallel-distributed processing approach was thought to be a superior way of explicating human (and artificial) cognition (see Gardner 1987). Perhaps it was just as well that, in 1983, I inadvertently refrained from offering a detailed processing characterization of each intelligence since, by 1990, such an account would have been considered deeply flawed. Still, because advances in science can come about only through the positing of detailed models that can be tested, refined, and refuted, I welcome efforts to "model" the different intelligences and to figure out how they work together.

Repeating the Sins of Intelligence Testing. Many critics of intelligence and intelligence testing believe that far from slaying the dragon, I have equipped it with additional horns or sharpened teeth. In their pessimistic view, seven intelligences are even worse than one: people can now feel inadequate across a whole ensemble of realms; and this taxonomy can be used further to stigmatize individuals and groups ("Johnny is bodily-kinesthetic"; "Sally is only linguistic"; "All girls are better in *X* than in *Y*"; "This ethnic group excels in *M* intelligence, while this racial group is better in *N* intelligence").

To these critics, let me say at once that MI theory was devised as a scientific theory and not as an instrument of social policy. Like any other theory, it can be put to different uses by different people; it is not possible, and may not be appropriate, for the originator of a theory to attempt to control the ways in which it is used. Nonetheless, I am personally opposed to the misuses implied in these criticisms. I do not think that the abuses of intelligence testing ought in any sense to be imported to multiple intelligences theory. Indeed, I do not believe that it is possible to assess intelligences in pure form, and the kinds of assessment I favor are entirely different from those associated with IQ testing. I discourage efforts to characterize individuals or groups as exhibiting one or another profile of intelligences. While at any moment a person or a group might exhibit certain intelligences, this picture is fluid and changing.

Indeed, the very lack of a developed intelligence of one sort can serve as a motivation for the development of that intelligence. In focusing in Chapter 14 on the Suzuki method of musical education, I wanted to demonstrate that a society's decision to invest significant resources into the development of a particular intelligence can make the entire society quite intelligent in that respect. Far from believing that intelligences are set in stone, I believe that they are subject to being considerably modified by changes in available resources and, for that matter, in one's perceptions of one's own abilities and potentials (Dweck and Licht 1980). The more one believes in the contextual and distributed views of intelligence, the less sense it makes to posit inherent limits on intellectual achievement.

I am sometimes asked whether I feel upset or betrayed by people who put my theory or concepts to uses I do not personally favor. Of course, such practices make me uneasy—but I cannot take responsibility for the uses or misuses to which my ideas are put by anyone who encounters them in the marketplace. Still, if someone who has worked with me were to apply the ideas in a way I could not endorse, I would ask him or her to develop a separate terminology and to desist from relating the work to my own.

Future Work

I assume that there will be continued give-and-take on the controversial aspects of MI theory; I hope for continued theoretical progress as well. For that progress I look chiefly to my students, who have already carried the work forward in ways that I admire (for example, Granott and Gardner, in press; Hatch and Gardner, in press; Kornhaber, Krechevsky, and Gardner 1990).

There is little question that educational work will continue to be carried out in the tradition of MI theory. Indeed, that work appears to be expanding with every month. I can no longer keep track of what is being done, let alone evaluate its quality. In *Multiple Intelligences: The Theory in Practice*, I have attempted to assess the state of the art at the present time. I expect to add to the set of educationally oriented writings assembled there; and I will also continue to serve as a clearinghouse for information about experiments and projects being carried out in an MI vein.

Any future work that I may do, building on the work described here, is likely to take on four forms:

1. *Studies of the diverse contexts in which intelligences develop and of the ways in which they develop in those contexts*. I have already carried out a detailed case study of intellectual options in another culture, the People's Republic of China (Gardner 1989); and, with several other colleagues, I am carrying out research on intelligence in the particular context of school (Gardner et al., in press).
2. *Studies of the phenomena of human creativity and how best to enhance it*. In my current project on creators of the modern era, I am

developing a method whereby it should be possible to study the nature of creative work across domains. In so doing, I am investigating the role played by different intelligences, and by different combinations of intelligences, in human creative achievement of the highest order. While building on MI theory, this focus on creativity expands the theory in several respects. Creativity depends upon more than intelligence: it involves personality factors in respect to the individual and domain and field factors at work in the larger society.

3. *An examination of the ethical dimensions of human intelligences*. Intelligences by themselves are neither prosocial nor antisocial. Goethe used his linguistic intelligence for positive ends, Goebbels, his for destructive ones; Stalin and Gandhi both understood other individuals but put their interpersonal intelligences to diverse uses. I am interested in two ethical dimensions of human intelligence. First, how can we ensure that every human being develops to the fullest his or her intellectual potentials? Second, how can we help to ensure the use of those intelligences for positive ends rather than for destructive ones? Both of these issues involve questions of policy and of "social engineering"—domains as new to me as they are treacherous. Yet, well into middle age, I feel a responsibility at least to consider these issues.
4. *A consideration of leadership for our times*. It has become a truism that ours is an era devoid of heroes and bereft of leadership. My own view is that we have a plentiful supply of leaders within domains: men and women who can, by dint of their achievements, supply leadership for scholarly disciplines, for the arts, for business, or for other technical areas. But we desperately lack leadership for the wider society: people who are able to speak (and to be heard) across interest groups and distinct areas of technical expertise and to address the broad concerns of society, and even of humanity as a whole.

I may have identified one reason for this apparent asynchrony. To provide leadership in a domain that highlights a certain intelligence, the principal requirement is that one excel in that intelligence: other people in that domain will come readily to follow this leader's example and to listen to what he or she has to say (or to watch what he or she does). We might say workers within a domain already share a common discourse. In the wider society, however, that person has no automatic, built-in way of attracting followers. Rather, a would-be leader must be able to create a story about that society—a persuasive narrative that accounts for his or her place within it and one that can link individuals of different intelligences, domains, and allegiances in a more incorporative enterprise.

Just where successful leadership lies is a subject for another day—though one, I hope, not too far in the future. It is clear to me that the issue of leadership will—indeed, must—go beyond multiple intelligences. It will involve capacities not dealt with in the present book—capacities that cut across intelligences and affect other people in ways that may be as emotional and social as they are cognitive. While from my present vantage point the best way to start to understand the human mind is to examine its different frames, its separate intelligences, in the end we must also learn how to yoke those intelligences together and mobilize them for constructive ends.

Cambridge, Massachusetts
November 1992

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PREFACE, 1983

As indicated in the following note about the Project on Human Potential, this book had an unusual genesis. It came to be written because of the foresight and generosity of a foundation that sought clarification of a concept in its charter—"human potential." The executive director of the foundation, Willem Welling, and the chairman of the board of directors, Oscar van Leer, conceived of a project to investigate human potential and asked several of us at the Graduate School of Education at Harvard to respond to their daunting challenge. The project drew together a group of colleagues from diverse backgrounds who have had the chance to collaborate over the past four years. The story of that collaboration will be related elsewhere, but it is germane to record that it has enabled me to range more broadly and to reflect more probingly about a gamut of issues than I could have done without the flexible support of the van Leer Foundation. My first and greatest debt is to Willem Welling, Oscar van Leer, and their associates at the Bernard van Leer Foundation.

I wish to thank my senior colleagues on the Project on Human Potential—Gerald Lesser, Robert LeVine, Israel Scheffler, and Merry White—for their continuous and continuing stimulation, constructive criticism, and support. Our interactions have genuinely changed the way in which I think about many issues and have helped materially with the writing and rewriting of this book. From the first, I have been blessed with incredibly talented, insightful, and hard-working research assistants, and I want to thank them individually and mention their area of contribution to this study: Lisa Brooks (genetics), Linda Levine (psychology), Susan McConnell (neurobiology), Susan Pollak (history and philosophy), William Skryzniarz (international development), and Claudia Strauss (anthropology). In a day when scholarship is little esteemed among talented young persons, they have shown exemplary independence and dedication: I am pleased that they are all pursuing careers in the world of scholarship. Other members of the project to whom I am indebted in various ways include Leonie Gordon, Margaret Herzig, Francis Keppel, Harry Lasker, and Lois Taniuchi. For their generous administrative support, I wish to thank deans Paul Ylvisaker and Blenda Wilson and, more recently, deans Patricia Graham and Jerome Murphy.

While, in the first instance, this book is a report on human potentials as viewed from a psychological perspective, it also represents an effort to pull together findings from two lines of research that I have been pursuing over the past dozen years. One line is the development, in normal and gifted children, of symbol-using capacities, particularly in the arts—a line I have been carrying out at Harvard Project Zero. The other has been the breakdown of cognitive capacities in individuals suffering from brain damage, which I have been pursuing at the Boston Veterans Administration Medical Center and the Boston University School of Medicine. A conception of different intelligences—the "frames of mind" of my title—has emerged as the most appropriate and comprehensive way of conceptualizing the human cognitive capacities whose development and breakdown I have been studying. I am grateful to have the opportunity to present in this volume the theoretical framework that has emerged from these efforts at synthesis, and to offer some tentative suggestions about the educational implications of the framework. And I want to take this opportunity to thank the various agencies that have generously supported my research over ten years: the Veterans Administration, which granted me a sabbatical so that I could concentrate on this synthesis; the Department of Neurology of Boston University School of Medicine; the Medical Research Division of the Veterans Administration; and the National Institute of Neurological Diseases, Communication Disorders, and Stroke, all of which have supported my work in neuropsychology; and, for their support of the work of my colleagues and me at Harvard Project Zero on normal and gifted children, the Spencer Foundation, the Carnegie Corporation, the Markle Foundation, the National Science Foundation, and the National Institute of Education. A large debt is owed to that innovative institution the MacArthur Foundation, which furnished me much-needed security during a perilous period for researchers in the social sciences.

I want finally to express my appreciation to those individuals who have made particular contributions to this book. A number of my colleagues

read the entire manuscript, or large sections of it, and offered extremely helpful comments. I wish to record my appreciation to Tom Carothers, Michael Cole, Yadin Dudai, David Feldman, Norman Geschwind, Linda Levine, David Olson, Susan McConnell, Sidney Strauss, William Wall, and Ellen Winner. Dolly Appel served as principal word processor and supervisor of the preparation of the physical manuscript and did so in a skillful, helpful, and cheerful manner that I greatly admired. Jasmine Hall generously offered to prepare the index. Linda Levine aided me with numerous aspects of the physical and conceptual manuscript and undertook with great ingenuity and energy the preparation of the extensive reference notes. I don't know what I would have done without her intelligences! And as with my two most recent books, my colleagues at Basic Books were an unfailing source of support: I especially thank my editor, Jane Isay, and her assistant, Mary Kennedy, as well as Judith Griessman, Janet Halverson, Phoebe Hoss, Lois Shapiro, and Vincent Torre—and the proofreader, Pamela Dailey.

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Cambridge, Massachusetts
June 1983

NOTE ON THE PROJECT ON HUMAN POTENTIAL, 1983

The Bernard van Leer Foundation of The Hague, Netherlands, is an international nonprofit institution dedicated to the cause of disadvantaged children and youth. It supports innovative projects that develop community approaches to early childhood education and child care, in order to help disadvantaged children to realize their potential.

In 1979, the foundation asked the Harvard Graduate School of Education to assess the state of scientific knowledge concerning human potential and its realization. Proceeding from this general directive, a group of scholars at Harvard has over the past several years been engaged in research exploring the nature and realization of human potential. Activities sponsored by the Project on Human Potential have included reviews of relevant literature in history, philosophy, and the natural and social sciences, a series of international workshops on conceptions of human development in diverse cultural traditions, and the commissioning of papers and books.

The principal investigators of the project represent a variety of fields and interests. Gerald S. Lesser, who chaired the project's steering committee, is an educator and developmental psychologist, a principal architect in the creation of educational television programs for children. Howard Gardner is a psychologist who has studied the development of symbolic skills in normal and gifted children, and the impairment of such skills in brain-damaged adults. Israel Scheffler is a philosopher who has worked in the areas of philosophy of education, philosophy of science, and philosophy of language. Robert LeVine, a social anthropologist, has worked in sub-Saharan Africa and Mexico, studying family life, child care, and psychological development. Merry White is a sociologist and Japan specialist who has studied education, formal organizations, and the roles of women in the Third World and Japan. This wide range of interests and disciplines enabled the project to take a multifaceted approach to issues of human potential.

The first volume published under the aegis of the Project on Human Potential is Howard Gardner's *Frames of Mind*, a study of human intellectual potentials that draws not only on psychological research but also on the biological sciences and on findings about the development and use of knowledge in different cultures.

The second book of the project to appear is Israel Scheffler's *Of Human Potential*, which treats philosophical aspects of the concept of potential. Sketching the background of the concept and placing it in the context of a general theory of human nature, this treatment then proposes three analytical reconstructions of the concept and offers systematic reflections on policy and the education of policy makers.

The third volume is *Human Conditions: The Cultural Basis of Educational Development*, by Robert A. LeVine and Merry I. White. Emphasizing the crucial role of cultural factors in the progress of human development, the book offers new models for development based on the social anthropology of the lifespan and the social history of family and school.

To provide background for the study of diversity in development, the project established teams of consultants in Egypt, India, Japan, Mexico, the People's Republic of China, and West Africa. Selected papers presented by these consultants in project workshops appear in *The Cultural Transition: Human Experience and Social Transformations in the Third World and Japan*, edited by Merry I. White and Susan Pollak. Representatives of international development agencies were also engaged as consultants and correspondents over the five-year period of the project. Through such international dialogue and research, the project has sought to create a new multidisciplinary environment for understanding human potential.

Frames of Mind

PART I

BACKGROUND

1

The Idea of Multiple Intelligences

A young girl spends an hour with an examiner. She is asked a number of questions that probe her store of information (Who discovered America? What does the stomach do?), her vocabulary (What does *nonsense* mean? What does *belfry* mean?), her arithmetic skills (At eight cents each, how much will three candy bars cost?), her ability to remember a series of numbers (5, 1, 7, 4, 2, 3, 8), her capacity to grasp the similarity between two elements (elbow and knee, mountain and lake). She may also be asked to carry out certain other tasks—for example, solving a maze or arranging a group of pictures in such a way that they relate a complete story. Some time afterward, the examiner scores the responses and comes up with a single number—the girl's intelligence quotient, or IQ. This number (which the little girl may actually be told) is likely to exert appreciable effect upon her future, influencing the way in which her teachers think of her and determining her eligibility for certain privileges. The importance attached to the number is not entirely inappropriate: after all, the score on an intelligence test does predict one's ability to handle school subjects, though it foretells little of success in later life.

The preceding scenario is repeated thousands of times every day, all over the world; and, typically, a good deal of significance is attached to the single score. Of course, different versions of the test are used for various ages and in diverse cultural settings. At times, the test is administered with paper and pencil rather than as an interchange with an examiner. But the broad outlines—an hour's worth of questions yielding one round number—are pretty much the way of intelligence testing the world around.

Many observers are not happy with this state of affairs. There must be more to intelligence than short answers to short questions—answers that predict academic success; and yet, in the absence of a better way of thinking about intelligence, and of better ways to assess an individual's capabilities, this scenario is destined to be repeated universally for the foreseeable future.

But what if one were to let one's imagination wander freely, to consider the wider range of performances that are in fact valued throughout the world? Consider, for example, the twelve-year-old male Puluwat in the Caroline Islands, who has been selected by his elders to learn how to become a master sailor. Under the tutelage of master navigators, he will learn to combine knowledge of sailing, stars, and geography so as to find his way around hundreds of islands. Consider the fifteen-year-old Iranian youth who has committed to heart the entire Koran and mastered the Arabic language. Now he is being sent to a holy city, to work closely for the next several years with an ayatollah, who will prepare him to be a teacher and religious leader. Or, consider the fourteen-year-old adolescent in Paris who has learned how to program a computer and is beginning to compose works of music with the aid of a synthesizer.

A moment's reflection reveals that each of these individuals is attaining a high level of competence in a challenging field and should, by any reasonable definition of the term, be viewed as exhibiting intelligent behavior. Yet it should be equally clear that current methods of assessing the intellect are not sufficiently well honed to allow assessment of an individual's potentials or achievements in navigating by the stars, mastering a foreign tongue, or composing with a computer. The problem lies less in the technology of testing than in the ways in which we customarily think about the intellect and in our ingrained views of intelligence. Only if we expand and reformulate our view of what counts as human intellect will we be able to devise more appropriate ways of assessing it and more effective ways of educating it.

Around the world many individuals involved in education are reaching similar conclusions. There is interest in new programs (some of them grandiose) that seek to develop human intelligence for a whole culture, to train individuals in such general skills as "anticipatory learning," to help individuals to realize their human potential. Intriguing experiments, ranging from the Suzuki method of training violin to the LOGO method of introducing the fundamentals of computer programming, seek to elicit accomplished performances from young children.* Some of these experiments have had demonstrated success while others are still in the pilot phase. Yet it is probably just to say that the successes as well as the failures have occurred in the absence of an adequate framework for thinking about intelligences. Certainly in no case does there exist a view of intelligence that incorporates the range of abilities I have just surveyed. To arrive at such a formulation is the purpose of the present book.

In the chapters that follow, I outline a new theory of human intellectual competences. This theory challenges the classical view of intelligence that most of us have absorbed explicitly (from psychology or education texts) or implicitly (by living in a culture with a strong but possibly circumscribed view of intelligence). So that the new features of this theory can be more readily identified, I will in these introductory pages consider some facts of the traditional view: where it came from, why it has become entrenched, what are some of the outstanding issues that remain to be resolved. Only then will I turn to the characteristics of the revisionist theory that I am propounding here.

For well over two thousand years, at least since the rise of the Greek city-state, a certain set of ideas has dominated discussions of the human condition in our civilization. This collection of ideas stresses the existence and the importance of mental powers—capacities that have been variously termed *rationality, intelligence,* or the deployment of *mind*. The unending search for an essence of humanity has led, with seeming ineluctability, to a focus on our species' quest for knowledge; and those capacities that figure in knowing have been especially valued. Whether it be Plato's philosopher-king, the Hebrew prophet, the literate scribe in a medieval monastery, or the scientist in a laboratory, the individual capable of using his** mental powers has been singled out. Socrates's "Know thyself," Aristotle's "All men by Nature desire to know," and Descartes's "I think: therefore I am" provide epigraphs that frame an entire civilization.

Even in that dark millennium that intervened between Classical times and the Renaissance, the ascendancy of intellectual factors was

* The sources for all quotations, research findings, and allied factual information will be found in the notes beginning on page 413.

** For ease of exposition the pronoun "he" will be used in its generic sense throughout this book.

rarely challenged. Early in the medieval period, St. Augustine, the very father of faith, declared:

> The prime author and mover of the universe is intelligence. Therefore, the final cause of the universe must be the good of the intelligence and that is truth. . . . Of all human pursuits, the pursuit of wisdom is the most perfect, the most sublime, the most useful, and the most agreeable. The most perfect, because in so far as a man gives himself up to the pursuit of wisdom, to that extent he enjoys already some portion of true happiness.

At the height of the Middle Ages, Dante put forth his view that "the proper function of the human race, taken in the aggregate, is to actualize continually the entire capacity possible to the intellect, primarily in speculation, then through its extension and for its sake, secondarily in action." And then, at the dawn of the Renaissance, a century before Descartes's time, Francis Bacon described the English ship in New Atlantis that comes upon a Utopian island whose chief institution is a great establishment devoted to scientific research. The ruler of this realm declares to visiting travelers:

> I will give the greatest jewel I have. For I will impart unto thee, for the love of God and men, a relation of the true state of Solomon's house. . . . The end of our foundation is the knowledge of causes, and secret motions of things; and the enlarging of the bounds of human empire, to the effecting of all things possible.

Of course, esteem for knowledge—and for those who appear to possess it—is not the only theme that haunts what we have come to term (somewhat inexactly) the Western world. The virtues of feeling, faith, and courage have also been leitmotifs over the centuries and, in fact, have sometimes (if not always justifiably) been contrasted with the quest for knowledge. What is instructive is that even when faith or love is extolled above all else, each is typically opposed to the powers of reason. In a parallel vein, when leaders of a totalitarian bent have sought to remake their societies in the light of a new vision, they have typically "put away" those rationalists or intellectuals whom they could not co-opt—once again paying a kind of perverse compliment to the powers of reason.

Reason, intelligence, logic, knowledge are not synonymous; and much of this book constitutes an effort to tease out the various skills and capacities that have too easily been combined under the rubric of "the mental." But, first, I must introduce a different kind of distinction—a contrast between two attitudes toward mind that have competed and alternated across the centuries. Adopting the appealing distinction of the Greek poet Archilochus, one can contrast those who view all intellect as a piece (let us dub them the "hedgehogs") with those who favor its fragmentation into several components (the "foxes"). The hedgehogs not only believe in a singular, inviolable capacity that is the special property of human beings: often, as a corollary, they impose the conditions that each individual is born with a certain amount of intelligence, and that we individuals can in fact be rank-ordered in terms of our God-given intellect or IQ. So entrenched is this way of thinking—and talking—that most of us lapse readily into rankings of individuals as more or less "smart," "bright," "clever," or "intelligent."

An equally venerable tradition of the West glorifies the numerous distinct functions or parts of the mind. In Classical times, it was common to differentiate between reason, will, and feeling. Medieval thinkers had their trivium of grammar, logic, and rhetoric, and their quadrivium of mathematics, geometry, astronomy, and music. As the science of psychology was launched, an even larger array of human mental abilities or faculties was posited. (Franz Joseph Gall, whom I shall formally introduce later, nominated 37 human faculties or powers of the mind; J. P. Guilford, a contemporary figure, favors 120 vectors of mind.) Some of the foxes also tend to the innate and rank-ordering cast of thought, but one can find many among them who believe in the altering (and ameliorating) effects of environment and training.

Dating back many centuries, debate between the hedgehogs and the foxes continues into our own time. In the area of brain study, there have been the *localizers*, who believe that different portions of the nervous system mediate diverse intellectual capacities; and these localizers have been arrayed against the *holists*, who deem major intellectual functions to be the property of the brain as a whole. In the area of intelligence testing, an interminable debate has raged between those (following Charles Spearman) who believe in a general factor of intellect and those (following L. L. Thurstone) who posit a family of primary mental abilities, with none preeminent among them. In the area of child development, there has been vigorous debate between those who postulate general structures of the mind (like Jean Piaget) and those who believe in a large and relatively unconnected set of mental skills (the environmental-learning school). Echoes in other disciplines are quite audible.

Thus, against a shared belief, over the centuries, in the primacy of intellectual powers, there is continuing debate about the propriety of parceling intellect into parts. As it happens, some long-standing issues in our cultural tradition show no signs of resolution. I doubt that topics like free will or the conflict between faith and reason will ever be resolved to everyone's satisfaction. But, in other cases, there may be hope for progress. Sometimes progress occurs as a consequence of logical clarification, as, for instance, when a fallacy is exposed. (No one continues in the mistaken belief that the distorted faces in El Greco's portraits were due to an astigmatic condition, once it has been explained that astigmatism would not lead to the painting of elongated faces. An astigmatic painter would *perceive* the faces on his canvas—and in the everyday world—to be elongated; but, in fact, these faces would appear completely normal to nonastigmatic eyes.) Sometimes progress results from dramatic scientific findings (the discoveries of Copernicus and Kepler radically changed our view about the architecture of the universe). And sometimes progress comes about when a large body of information is woven together in a convincing tapestry of argument (as happened when, in the course of introducing his theory of evolution, Charles Darwin reviewed masses of evidence about the development and differentiation of species).

The time may be at hand for some clarification about the structure of human intellectual competence. In the present case, there is neither a single scientific breakthrough nor the discovery of an egregious logical blunder, but rather the confluence of a large body of evidence from a variety of sources. Such a confluence, which has been gathering with even greater force over the past few decades, seems to be recognized (at least in peripheral vision) by those concerned with human cognition. But the lines of convergence have rarely, if ever, been focused on directly and systematically examined in one place; and they certainly have not been shared with the wider public. Such confrontation and collation are the twin purposes of this book.

In what follows, I argue that there is persuasive evidence for the existence of several *relatively autonomous* human intellectual competences, abbreviated hereafter as "human intelligences." These are the "frames of mind" of my title. The exact nature and breadth of each intellectual "frame" has not so far been satisfactorily established, nor has the precise number of intelligences been fixed. But the conviction that there exist at least some intelligences, that these are relatively independent of one another, and that they can be fashioned and combined in a multiplicity of adaptive ways by individuals and cultures, seems to me to be increasingly difficult to deny.

Previous efforts (and there have been many) to establish independent intelligences have been unconvincing, chiefly because they rely on only one or, at the most, two lines of evidence. Separate "minds" or "faculties" have been posited solely on the basis of logical analysis, solely on the history of educational disciplines, solely on the results of intelligence testing, or solely on the insights obtained from brain study. These solitary efforts have rarely yielded the same list of competences and have thereby made a claim for multiple intelligences seem that much less tenable.

My procedure is quite different. In formulating my brief on behalf of multiple intelligences, I have reviewed evidence from a large and hitherto unrelated group of sources: studies of prodigies, gifted individuals, brain-damaged patients, idiots savants, normal children, normal adults, experts in different lines of work, and individuals from diverse cultures. A preliminary list of candidate intelligences has been bolstered (and, to my mind, partially validated) by converging evidence from these diverse sources. I have become convinced of the existence of an intelligence to the extent that it can be found in relative isolation in special populations (or absent in isolation in otherwise normal populations); to the extent that it may become highly developed in specific individuals or in specific cultures; and to the extent that psychometricians, experimental researchers, and/or experts in particular disciplines can posit core abilities that, in effect, define the intelligence. Absence of some or all of these indices of course eliminates a candidate intelligence. In ordinary life, as I will show, these intelligences typically work in harmony, and so their autonomy may be invisible. But when the appropriate observational lenses are donned, the peculiar nature of each intelligence emerges with sufficient (and often surprising) clarity.

The major assignment in this book, then, is to make the case for the existence of multiple intelligences (later abbreviated as MI). Whether or not the case for specific intelligences proves persuasive, I shall at least have gathered between two covers several bodies of knowledge that have hitherto lived in relative segregation. In addition, however, this volume has a number of other, and not wholly subsidiary, purposes—some primarily scientific, others distinctly practical.

First of all, I seek to expand the purviews of cognitive and developmental psychology (the two areas to which, as a researcher, I feel the closest). The expansion that I favor looks, in one direction, toward the biological and evolutionary roots of cognition and, in the other direction, toward cultural variations in cognitive competence. To my mind, visits to the "lab" of the brain scientist and to the "field" of an exotic culture should become part of the training of individuals interested in cognition and development.

Second, I wish to examine the educational implications of a theory of multiple intelligences. In my view, it should be possible to identify an individual's intellectual profile (or proclivities) at an early age and then draw upon this knowledge to enhance that person's educational opportunities and options. One could channel individuals with unusual talents into special programs, even as one could devise prosthetics and special enrichment programs for individuals presenting an atypical or a dysfunctional profile of intellectual competences.

Third, I hope that this inquiry will inspire educationally oriented anthropologists to develop a model of how intellectual competences may be fostered in various cultural settings. Only through such efforts will it be possible to determine whether theories of learning and teaching travel readily across national boundaries or must be continually refashioned in light of the particularities of each culture.

Finally—this is the most important, but also the most difficult, challenge—I hope that the point of view that I articulate here may prove of genuine utility to those policy makers and practitioners charged with "the development of other individuals." Training and heightening of intellect is certainly "in the international air": the World Bank's report on Human Development, the Club of Rome's essay on anticipatory learning, and the Venezuelan Project on Human Intelligence are but three recent visible examples. Too often, practitioners involved in efforts of this sort have embraced flawed theories of intelligence or cognition and have, in the process, supported programs that have accomplished little or even proved counterproductive. To aid such individuals, I have developed a framework that, building on the theory of multiple intelligences, can be applied to any educational situation. If the framework put forth here is adopted, it may at least discourage those interventions that seem doomed to failure and encourage those that have a chance for success.

I regard the present effort as a contribution to the emerging science of cognition. To a considerable extent, I am summarizing the work of other scholars; but, to a certain extent (and I intend to make clear where), I am proposing a new orientation. Some of the claims are controversial, and I expect that experts versed in cognitive science will eventually have their say as well. Part II, the "heart" of the book, consists of a description of several intellectual competences of whose existence I feel reasonably certain. But, as befits a potential contribution to science, I shall first (in Chapter 2) review other efforts to characterize intellectual profiles and then, after putting forth the evidence in support of my theory, will (in Chapter 11) subject that point of view to lines of criticism. As part of my mission to broaden the study of cognition, I adopt a biological and cross-cultural perspective throughout Part II and also devote a separate chapter each to the biological bases of cognition (Chapter 3) and to cultural variations in education (Chapter 13). Finally, given the "applied" agenda I have just sketched, I shall in the concluding chapters of the book address more directly questions of education and policy.

A word, finally, about the title of this chapter. As I have indicated, the idea of multiple intelligences is an old one, and I can scarcely claim any great originality for attempting to revive it once more. Even so, by featuring the word *idea* I want to underscore that the notion of multiple intelligences is hardly a proven scientific fact: it is, at most, an idea that has recently regained the right to be discussed seriously. Given the ambition and scope of this book, it is inevitable that this idea will harbor many shortcomings. What I hope to establish is that "multiple intelligences" is an idea whose time has come.

2

Intelligence
Earlier Views

As a schoolboy growing up in the latter part of the eighteenth century, Franz Joseph Gall observed a relationship between certain mental characteristics of his schoolmates and the shapes of their heads. For instance, he noted that those boys with prominent eyes tended to have good memories. He clung to this idea as he became a physician and scientist and, some years later, placed it at the center of a discipline called "phrenology" that aspired to be a science.

The key idea of phrenology is simple. Human skulls differ from one another, and their variations reflect differences in the size and the shape of the brain. Different areas of the brain, in turn, subserve discrete functions; and so, by carefully examining the skull configurations of an individual, an expert should be able to determine the strengths, the weaknesses, and the idiosyncrasies of his or her mental profile.

Gall's list of powers and "organs" of the mind, as modified by his colleague, Joseph Spurzheim, was a mixed bag. Featured were some thirty-seven different powers that included affective faculties, such as amativeness, philoprogenitiveness, and secretiveness; sentiments like hope, reverence, and self-esteem; reflective powers and perceptual capacities, including language, tune (for music), as well as sensitivity to such visual properties as shape and color.

It should come as no surprise (at least to observers of best-sellers over the years) that the phrenology of Gall and Spurzheim achieved enormous popularity in Europe and the United States during the early part of the nineteenth century. The simple doctrine had intrinsic appeal, and every individual could "play the game." The popularity of the aspiring science was strengthened by the fact that it was endorsed by many scientists of the day.

Of course, armed with hindsight, one can readily spot the flaws in the phrenological doctrine. We know, for example, that the sheer size of the brain has no clear-cut correlation with an individual's intellect; in fact, individuals with very small brains, such as Walt Whitman and Anatole France, have achieved great success, even as individuals with massive brains are sometimes idiots and all too often decidedly unremarkable. Moreover, the size and configuration of the skull itself proves an inexact measure of the important configurations of the human cortex.

Nonetheless, even as it would be unpardonable to overlook the flaws in Gall's claims, it would be equally fallacious to dismiss them entirely. Gall, after all, was among the first modern scientists to stress that different parts of the brain mediate different functions; the fact that we are not yet able to pinpoint specifically the relationship between size, shape, and function should by no means be taken as proof that we will never be able to do so. Moreover, Gall proposed other pregnant ideas, among them this fascinating claim: there do not exist general mental powers, such as perception, memory, and attention; but, rather, there exist different forms of perception, memory, and the like for *each* of the several intellectual faculties, such as language, music, or vision. Though seldom taken seriously throughout most of the history of psychology, this idea proves to be highly suggestive and may well be correct.

The century following Gall's original claims has seen repeated oscillations between a belief in localization of function and a skepticism about this entire line of brain-behavior correlations: in fact, this oscillation continues to plague us today. The first dubious voices were raised in the decades following Gall's original publications in the early 1800s: scholars like Pierre Flourens showed, by extirpating different parts of the brain of an animal and then observing its new behavior, that some of Gall's claims could not be supported. But then a strong chorus of support came in the 1860s, when the French surgeon and anthropologist Pierre-Paul Broca demonstrated, for the first time, an indisputable relationship between a specific brain lesion and a particular cognitive impairment. In particular, Broca amassed evidence that a lesion in a certain area of the left anterior portion of the human cortex caused aphasia, the breakdown of linguistic capacities. This dramatic demonstration was followed in succeeding years by ample documentation that various lesions in the left hemisphere could impair particular linguistic functions along specifiable lines. One lesion would reliably impair reading, while another would compromise naming or repetition. Localization of function, if not phrenology, once more carried the day.

Attempts to relate the brain to mental function or, for that matter, to uncover the physical roots of mental functions antedated the nineteenth century. The Egyptians had located thought in the heart, and judgment in the head or kidneys. Pythagoras and Plato had held the mind to be in the brain. Analogously, Aristotle thought that the seat of life is in the heart, while Descartes placed the soul in the pineal gland. Scientists of the nineteenth century were not the first to try to break down the range of human intellectual abilities (though a list of thirty-seven was on the longish side). Plato and Aristotle had certainly been interested in varieties of rational thought and forms of knowledge. During the Middle Ages, scholars dwelled upon the trivium and the quadrivium, those realms of knowledge that every educated person mastered. The Hindu Upanishads actually describe seven kinds of knowledge. What the nineteenth century ushered in were highly specific claims about the profile of human mental capacities and, eventually, empirically based efforts in the clinic and the experimental laboratory to relate specific areas of the brain to particular cognitive functions.

Psychology Proper

Efforts to set up psychology as a science began in earnest in the latter half of the nineteenth century, with scholars like Wilhelm Wundt in Germany and William James in America providing a rationale and leading the way. Because the history of prescientific psychology was entangled with philosophy rather than with medicine, and because the first psychologists themselves were eager to define their discipline as separate from physiology and neurology, there was relatively little contact between the new breed of psychologists and the individuals who were conducting experiments with the human brain. Perhaps as a result, the categories of mentation that interested psychologists proved to be remote from those that had engaged students of the brain. Rather than thinking (like Gall) in terms of particular mental contents (like language, music, or various forms of visual perception), psychologists searched (and have continued to search) for the laws of broad, "horizontal" mental faculties—abilities like memory, perception, attention, association, and learning; these faculties were thought to operate equivalently—in fact, blindly—across diverse contents, independent of the particular sensory modality or the type of ideational content involved in the domain. In fact, such work continues to this day and makes remarkably little contact with findings emanating from the brain sciences.

Thus, one strand of scientific psychology has searched for the most general laws of human knowing—what might today be called the principles of human information processing. An equally energetic area of study has searched for individual differences—the distinctive profiles of abilities (and disabilities) in individuals. The British polymath Sir Francis Galton was instrumental in launching this field of inquiry a century ago. Given his particular interest in genius, eminence, and other notable forms of accomplishment, Galton developed statistical methods that made it possible to rank human beings in terms of their physical and intellectual powers and to correlate such measures with one another. These tools enabled him to verify a suspected link between genealogical lineage and professional accomplishment.

In fact, if one were going to measure individuals, one needed numerous dimensions and tasks on which to measure and compare. It was only a matter of time before psychologists devised various tests and began to rank human beings by comparing performances on these measures. At first, the prevailing wisdom held that powers of intellect could be estimated adequately by various tasks of sensory discrimination—for example, the ability to distinguish among lights, among weights, or among tones. Galton, in fact, believed that more refined and learned individuals would be characterized by especially keen sensory capacities. But gradually (for a variety of reasons) the scientific community concluded that one would have to look principally at more complex or "molar" capacities, such as those involving language and abstraction, if one wished to gain a more accurate assessment of human intellectual powers. The chief worker in this area was the Frenchman Alfred Binet. At the beginning of the twentieth century, with his colleague Theodore Simon, Binet devised the first tests of intelligence in order to sift out retarded children and to place other children at their appropriate grade level.

Within the scientific community and the larger society, excitement over intelligence testing was at least as pronounced and was much more prolonged than had been the enthusiasm about phrenology almost a century earlier. The tasks and tests were soon available for widespread use: the mania for evaluating people for specific purposes—be it school, the military, placement in industrial organizations, or even social companionship—fueled the excitement over intelligence testing. At least until recent years, most psychologists would agree with the assessment that intelligence testing was psychology's greatest achievement, its chief claim to social utility, and an important scientific discovery in its own right. They might even applaud the British psychologist H. J. Eysenck's conclusion that the concept of intelligence "constitutes a true scientific paradigm in the Kuhnian* sense."

The tale describing the rise of the IQ test, and the various debates that have raged about it, has been retold so many times that I am relieved of the necessity to relate the sound and fury once again. Most scholars within psychology, and nearly all scholars outside the field, are now convinced that enthusiasm over intelligence tests has been excessive, and that there are numerous limitations in the instruments themselves and in the uses to which they can (and should) be put. Among other considerations, the tasks are definitely skewed in favor of individuals in societies with schooling and particularly in favor of individuals who are accustomed to taking paper-and-pencil tests, featuring clearly delineated answers. As I have noted, the tests have predictive power for success in schooling but relatively little predictive power outside the school context, especially when more potent factors like social and economic background have been taken into account. Too much of a hullabaloo over the possible heritability of IQ has been sustained over the past few decades; and while few authorities would go so far as to claim that the IQ is in no degree inherited, extreme claims on heritability within and across races have been discredited.

Still, one long-standing debate within the area of intelligence testing must be briefly rehearsed here. On one side are arrayed those individuals influenced by the British educational psychologist Charles Spearman—in my terms, a "hedgehog"—who believe in the existence of "g"—a general overriding factor of intelligence that is measured by every task in an intelligence test. On the other side are supporters of the American psychometrician and "fox" L. L. Thurstone, who believe in the existence of a small set of primary mental faculties that are relatively independent of one another and are measured by different tasks. Thurstone, in fact, nominated

* Eysenck refers here to Thomas Kuhn, a contemporary philosopher who defines sciences in terms of their central assumptions and procedures, or "paradigms."

seven such factors—verbal comprehension, word fluency, numerical fluency, spatial visualization, associative memory, perceptual speed, and reasoning. (Other less widely quoted scholars posit a far higher number of independent factors.)

Most important to stress is that neither side has been able to gain an upper hand. That is because the issues surrounding the interpretation of intelligence scores turn out to be mathematical in nature and not susceptible to empirical resolution. Thus, given the same set of data, it is possible, using one set of factor-analytic procedures, to come up with a picture that supports the idea of a "g" factor; using another equally valid method of statistical analysis, it is possible to support the notion of a family of relatively discrete mental abilities. As Stephen Jay Gould has shown in his recent book, *The Mismeasure of Man*, there is nothing intrinsically superior about either of these mathematical measures. When it comes to the interpretation of intelligence testing, we are faced with an issue of taste or preference rather than one on which scientific closure is likely to be reached.

Piaget

It is from an individual originally trained in the IQ tradition that we have obtained a view of intellect that has, in many quarters, replaced the vogue of intelligence testing. The Swiss psychologist Jean Piaget began his career around 1920 as a researcher working in Simon's laboratory and soon became particularly interested in the errors children make when tackling items on an intelligence test. Piaget came to believe that it is not the accuracy of the child's response that is important but rather the lines of reasoning the child invokes: these can be most clearly seen by focusing on the assumptions and the chains of reasoning that spawn erroneous conclusions. So, for example, it was not revealing in itself to discover that most four-year-olds think that a hammer is more like a nail than like a screwdriver; what was important is that children reach this conclusion because their view of similarity reflects physical co-occurrence (hammers are found in the vicinity of nails) rather than membership in the same hierarchical category (tools).

Piaget himself never undertook a critique of the intelligence-testing movement; but in looking at the scientific moves he made, one can gain a feeling for some of the inadequacies of the Binet-Simon program. First of all, the IQ movement is blindly empirical. It is based simply on tests with some predictive power about success in school and, only marginally, on a theory of how the mind works. There is no view of process, of how one goes about solving a problem: there is simply the issue of whether one arrives at a correct answer. For another thing, the tasks featured in the IQ test are decidedly microscopic, are often unrelated to one another, and seemingly represent a "shotgun" approach to the assessment of human intellect. The tasks are remote, in many cases, from everyday life. They rely heavily upon language and upon a person's skill in defining words, in knowing facts about the world, and in finding connections (and differences) among verbal concepts.

Much of the information probed for in intelligence tests reflects knowledge gained from living in a specific social and educational milieu. For instance, the ability to define *tort* or to identify the author of the *Iliad* is highly reflective of the kind of school one attends or the tastes of one's family. In contrast, intelligence tests rarely assess skill in assimilating new information or in solving new problems. This bias toward "crystallized" rather than "fluid" knowledge can have astounding consequences. An individual can lose his entire frontal lobes, in the process becoming a radically different person, unable to display any initiative or to solve new problems—and yet may continue to exhibit an IQ close to genius level. Moreover, the intelligence test reveals little about an individual's potential for further growth. Two individuals can receive the same IQ score, yet one may turn out to be capable of a tremendous spurt in intellectual attainment while another may be displaying the very height of his intellectual powers. To put it in the terms of the Soviet psychologist Lev Vygotsky, intelligence tests fail to yield any indication of an individual's "zone of potential [or "proximal"] development."

With such critical considerations at least implicitly in mind, Piaget developed over several decades a radically different and extremely powerful view of human cognition. In his view, all study of human thought must begin by positing an individual who is attempting to make sense of the world. The individual is continually constructing hypotheses and thereby attempting to generate knowledge: he is trying to figure out the nature of material objects in the world, how they interact with one another, as well as the nature of persons in the world, their motivations, and their behavior. Ultimately he must piece them all together into a sensible story, a coherent account of the nature of the physical and the social worlds.

Initially, the baby makes sense of the world, primarily through his reflexes, his sensory perceptions, and his physical actions upon the world. After a year or two, he arrives at a "practical" or "sensori-motor" knowledge of the world of objects, as they exist in time and space. Equipped with this knowledge, he can make his way satisfactorily in his environment and can appreciate that an object continues to exist in space and time even when it is out of view. Next the toddler goes on to develop *interiorized actions* or *mental operations*. These are actions that can potentially be performed upon the world of objects; but, owing to a newly emerging capacity, these actions need only be performed cerebrally, within the head, perhaps through imagery. So, for example, to proceed from his destination to a familiar starting point, the child does not have to try out various routes: he can simply calculate that by reversing his steps, he will return to his origin. At the same time, the child also becomes capable of symbol use: now he can use various images or elements—such as words, gestures, or pictures—to stand for real life objects in the world, and can become skilled in deploying various *symbol systems*, like language or drawing.

These evolving capacities of *interiorization* and *symbolization* reach a high point around the age of seven or eight, when the child becomes capable of *concrete operations*. Armed with this new set of capacities, the child is now able to reason systematically about the world of objects, number, time, space, causality, and the like. No longer confined simply to acting in a physically appropriate manner with objects, the child can now appreciate the relations that obtain among a series of actions upon objects. So he understands that objects can be rearranged and still remain the same quantity; that a material can be changed in shape without the mass being thereby affected; that a scene can be viewed from a different perspective and still contain the same elements.

According to Piaget, a final stage of development comes into being during early adolescence. Now capable of *formal operations*, the youth is able to reason about the world not only through actions or single symbols but rather by figuring out the implications that obtain among a set of related propositions. The adolescent becomes able to think in a completely logical fashion: now resembling a working scientist, he can express hypotheses in propositions, test them, and revise the propositions in light of the results of such experimentation. These abilities in hand (or in head), the youth has achieved the end-state of adult human cognition. He is now capable of that form of logical-rational thought that is prized in the West and epitomized by mathematicians and scientists. Of course, the individual can go on to make further discoveries, but he will no longer undergo any further qualitative changes in his thinking.

This sprint through Piaget's principal precepts highlights some of the strengths and the weaknesses of his formulation. On the positive side, Piaget has taken children seriously; he has posed to them problems of importance (particularly ones drawn from the scientific realm) and has adduced evidence that, at each stage, the same underlying organized structure can be discerned across a wide range of mental operations. For instance, in Piaget's view, the "concrete-operational" child is capable of handling a gamut of tasks having to do with conservation of number, causality, quantity, volume, and the like, because they all draw upon the same core mental structures. Similarly, equipped with formal operations, the adolescent displays a structured whole of operations so that he can now reason logically about any set of propositions posed to him. Unlike the architects of intelligence testing, Piaget has also taken seriously the list of issues that philosophers, and most especially Immanuel Kant, deemed central to human intellect, including the basic categories of time, space, number, and causality. At the same time, Piaget has avoided forms of knowledge that are simply memorized (like word definitions) or restricted to certain cultural groups (such as those that favor "high" art). Wittingly or not, Piaget has limned a brilliant portrait of that form of human intellectual growth that is valued most highly by the Western scientific and philosophical traditions.

But these undeniable strengths, which have made Piaget *the* theorist of cognitive development, cohabit with certain weaknesses that have become increasingly clear over the past two decades. First of all, while Piaget has painted a redoubtable picture of development, it is still only one sort of development. Centered on the intellectual agenda addressed by the young scientist, Piaget's model of development assumes relatively less importance in non-Western and preliterate contexts and may, in fact, be applicable only to a minority of individuals, even in the West. The steps entailed in achieving other forms of competence—those of an artist, a lawyer, an athlete, or a political leader—are ignored in Piaget's monolithic emphasis upon a certain form of thinking.

Of course, Piaget's perspective might be limited, yet totally accurate within its own restricted domain. Alas, a generation of empirical researchers who have looked closely at Piaget's claims have found otherwise.

While the broad outlines of development as sketched by Piaget remain of interest, many of the specific details are simply not correct. Individual stages are achieved in a far more continuous and gradual fashion than Piaget indicated; in fact, one finds little of the discontinuity that he claimed (and that made his theoretical claims particularly riveting). Thus, most tasks claimed to entail concrete operations can be solved by children in the pre-operational years, once various adjustments have been introduced into the experimental paradigm. For example, there is now evidence that children can conserve number, classify consistently, and abandon egocentrism as early as the age of three—findings in no way predicted (or even allowed) by Piaget's theory.

Another claim central to Piaget's theory has also fallen on hard times. He contended that the various operations that he had uncovered could be applied to any manner of content. (In this, he resembled the proponents of "horizontal faculties" who believe in all-encompassing processes like perception or memory.) In reality, however, Piaget's operations emerge in a much more piecemeal fashion, proving effective with certain materials or contents while failing to be invoked (or being invoked improperly) with other materials. Thus, for example, a child who exhibits the operation of conservation with some materials will fail to conserve with other materials. Piaget was aware that operations would not crystallize instantaneously: he even invented a "fudge factor"—called *décalage*—which allowed the same underlying operation to emerge at somewhat different times with different materials. But what has happened is that *décalage* has, in fact, become the rule in studies of cognitive development. Rather than a whole series of abilities coalescing at about the same time (as Piaget would have it), theoretically related abilities turn out to emerge at disparate points in time.

One confronts other limitations as well. Despite his skepticism about IQ items couched in language, Piaget's tasks themselves are usually conveyed verbally. And when they have been posed nonlinguistically, the results are often different from those obtained in Genevan laboratories. While Piaget's tasks are more molar and complex than those favored in intelligence tests, many still end up fairly remote from the kind of thinking in which most individuals engage during their normal daily lives. Piaget's tasks continue to be drawn from the benches and blackboards of a laboratory scientist. Finally, somewhat surprisingly, although his picture of the active, exploring child strikes a responsive chord, Piaget tells us little about creativity at the forefront of the sciences, let alone about the originality that is most prized in the arts or other realms of human creativity. Over and above its failure to convey the universal pattern of cognitive growth that all normal children are alleged to traverse, Piaget's scheme—restricted at its mature end to the classroom exercises of a high-school science class—emerges as even less relevant to that discovery of new phenomena or that positing of new problems that many consider central in the life of the mind. Piaget's scheme may well be the best that we have, but its deficiencies are becoming all too evident.

The Information-Processing Approach

If intelligence testing was the vogue forty years ago, and Piagetian theory the rage twenty years ago, a new form of study, often called "information-processing psychology" or "cognitive science," is currently enjoying hegemony among students of the mind. The information-processing psychologist uses the methods devised by experimental psychologists over the past century in order to investigate tasks of the sort that Piaget and other more molar cognitive theorists have been employing. As an example, a researcher working in the information-processing paradigm seeks to provide a second-by-second (or even a millisecond by millisecond) "microgenetic" picture of the mental steps involved as a child solves (or fails to solve) a conservation problem. The process begins with information delivered to eye or ear and only concludes when an answer has been issued by mouth or hand. Rather than simply describing two or three basic stages found at different ages, and the strategies favored at each point, as Piaget would do, the information-processing psychologist attempts to describe in the finest detail all steps used by a given child. In fact, an ultimate goal of information-processing psychology is to describe the steps so exhaustively and scrupulously that an individual's performance can be simulated on a computer. Such a descriptive *tour de force* involves detailed analysis of the task itself, as well as painstaking analysis of the subject's thoughts and behavior.

In its focus on the details of processing, and in its illumination of the microstructure of a task, information-processing intelligence theory is an advance over earlier lines of study. We now have available a much more dynamic view of what happens in the course of problem solving: included is a picture of the informational "intake" or access mechanisms; the forms of immediate and short-term retention that hold onto information until it can be encoded in memory; various recoding and transforming operations that can be imposed upon the newly acquired information. Moreover, there is the suggestive notion of executive functions, "meta-components" or other higher-order control mechanisms, whose mission it is to determine which problems ought to be tackled, which goals sought, which operations applied, and in which order. Throughout, one encounters the healthy, if somewhat unexamined, American emphasis on mechanics: on what is done, in what order, and by what mechanism, in order to yield a particular effect or result.

Information-processing psychology, then, represents progress along certain—but not, in my view, all—lines. In opposition to the Piagetian paradigm, for example, information-processing psychology lacks an articulated theory within which different forms of cognition can be convincingly related to (or distinguished from) one another. Oftentimes, a survey of the literature suggests the existence of a thousand expert information processors carrying out one or another operation without any particular connection to the others. But, like Piaget, information-processing psychologies sometimes commit the opposite sin as well: one encounters the blithe notion that a single highly general problem-solving mechanism can be brought to bear willy-nilly on the full range of human problems. While in theory the idea of a single "horizontal" problem-solving apparatus is attractive, in fact the carefully selected problems to which it is said to apply turn out to be disturbingly similar to one another. Thus, the claim that we use the same problem-solving apparatus across the board becomes vacuous. In fact, in common with Piagetian psychology, nearly all the problems examined by information-processing psychologists prove to be of the logical-mathematical sort. The prototypical problems—solving logical theorems, carrying out geometric proofs, playing a game of chess—might well have been borrowed directly from Piaget's archive of pivotal intellectual tasks.

As information-processing psychology is still in its infancy, it is perhaps unfair to criticize it for not having solved major outstanding issues in the area of intelligence. Moreover, recent flirtation with the "intelligence-testing" industry has infused with new life this somewhat discredited branch, as researchers like Robert Sternberg have attempted to identify the operations involved in the solution of standard intelligence test items. Yet, to my mind, the excessively mechanistic computer-driven model for thinking and the penchant for scientifically oriented test problems foreshadow certain long-term problems with this approach. For one thing, like most previous approaches to intelligence, the information-processing tack is studiously non- (if not anti-) biological, making little contact with what is known about the operation of the nervous system. For another, there is as yet relatively little interest in the open-ended creativity that is crucial at the highest levels of human intellectual achievement. The problems posed characteristically feature a single solution or small set of solutions, and there is scant attention to problems with an indefinite range of solutions, let alone the generation of new problems.

Finally, a more serious objection. At present, there seems to be no procedure by which to adjudicate among the principal debates within the area of information-processing psychology. Is there a central executive or not? Are there general problem-solving skills or just skills specific to particular domains? What elements change with development—the number and size of storage areas, the kinds of strategy available, or the efficiency with which operations are carried out? The information-processing psychologists could retort, "This criticism is true at present but will become less true as we accrue more data. When we succeed in producing a sufficiently rich set of computer simulations, we will determine *which* simulation most closely mimics the thoughts and behavior of human beings."

But as I see it, it is far too easy to spin out simulations that can support rival lines of argument, or to counter an apparent refutation of a model simply by effecting minor adjustments in a task. Should one psychologist claim that short-term memory may contain more than the reported "magic number" of seven chunks, a defender of the classic position can simply count the chunks differently or claim that what had been four chunks have been "re-chunked" into two. More generally, unless one can envision a decisive test between one information-processing approach and another, one is faced with the likelihood that there will be as many convincing information-flow box diagrams as there are ingenious researchers.

The "Symbol Systems" Approach

Investigations that accentuate one view of human intellect naturally breed a counter movement. As we have seen, the IQ, the Piagetian, and the information-processing approaches all focus on a certain kind of logical or linguistic problem solving; all ignore biology; all fail to come to grips with the higher levels of creativity; and all are insensitive to the range of roles highlighted in human society. Consequently, these facts have engendered an alternative point of view that focuses precisely on these neglected areas.

I cannot write about this fledgling movement in a disinterested way because it is closest to my own work and my own beliefs. It is perhaps best to regard this final section as an introduction to the argument being developed throughout the remainder of the book, rather than as a mere conclusion to the survey undertaken in this chapter. As a symbol of this move, I shall adopt the collaborative "we" in describing the principal features of this approach.

For much of the twentieth century, philosophers have displayed a particular interest in human symbolic capacities. According to such influential thinkers as Ernst Cassirer, Susanne Langer, and Alfred North Whitehead, the ability of human beings to use various symbolic vehicles in expressing and communicating meanings distinguishes human beings sharply from other organisms. Symbol use has been key in the evolution of human nature, giving rise to myth, language, art, and science; it has also been central in the highest creative achievements of human beings, all of which exploit the human symbolic faculty.

We may speak of two "paradigm" shifts in philosophy. Initially, the philosophical interest of Classical times in objects of the physical world was replaced by that preoccupation with the mind and its objects that we associate with Hume, Kant, and other Enlightenment thinkers. In the twentieth century, however, the focus shifted once again, this time to the actual symbolic vehicles of thought. Thus, much of contemporary work in philosophy is directed toward an understanding of language, mathematics, visual arts, gestures, and other human symbols.

We can observe the same trends at work in psychology. There, too, we discern a shift from external behavior to the activities and products of human minds and, specifically, to the various symbolic vehicles in which human individuals traffic. Rather than considering symbolic vehicles (or the media by which they are transmitted) as transparent means by which the same contents are presented, a number of researchers—including David Feldman, David Olson, Gavriel Salomon, and myself—have elected to take human symbol systems as a primary focus of attention. In our view, much of what is distinctive about human cognition and information processing involves the deployment of these various symbol systems. It is at least an open question, an empirical issue, whether operation of one symbol system such as language involves the same abilities and processes as such cognate systems as music, gesture, mathematics, or pictures. It is equally open whether information encountered in one medium (say, film) is the "same" information when transmitted by another medium (say, books).

In adopting this symbolic perspective, my colleagues and I do not propose to throw away the Piagetian baby with the bath water. Rather, we seek to use the methods and the overall schemes fashioned by Piaget and to focus them not merely on the linguistic, logical, and numerical symbols of classic Piagetian theory but rather upon a full range of symbol systems encompassing musical, bodily, spatial, and even personal symbol systems. The challenge, as we see it, is to compose a developmental portrait of each of these forms of symbolic competence and to determine empirically which connections or distinctions might obtain across them.

The problem of reconciling a pluralistic approach to cognition with Piaget's unilineal developmental scheme has been well addressed by David Feldman. According to this educationally oriented developmental psychologist, cognitive accomplishments may occur in a range of domains. Certain domains, such as the logical-mathematical one studied by Piaget, are *universal*. They must be (and are) confronted and mastered by individuals all over the world, simply by virtue of their membership in the same species and the resultant need to cope with that species' physical and social environment. Other domains are restricted to *certain cultures*. For example, the capacity to read is important in many cultures but unknown (or minimally valued) in others. Unless one lives in a culture where this domain is featured, one will make little or no progress in it. Still other domains are restricted to pockets within a culture. For example, map making is important in some literate subcultures but not in others. One also encounters domains that are highly idiosyncratic. Chess playing, the mastery of the Japanese game of go, and expertise in crossword puzzles are not essential in any division of society, and yet some individuals realize tremendous achievements in those domains, within a particular culture.

Finally, arrayed at the opposite extreme from universal domains are *unique* domains, areas of skill in which initially only one or a tiny handful of individuals make progress. One might think of the innovative scientist or artist as working in a unique domain, a domain of which he is currently the only denizen. What is particularly fascinating is that, eventually, unique domains may become so well explored and articulated by an individual or a small group that they become accessible to other individuals. Many scientific or artistic breakthroughs, such as calculus or the theory of evolution, initially began as unique domains but now can be mastered by large segments of a culture. And perhaps the same thing occurred in the remote past in such cultural domains as map making or reading.

A focus on the mastery of domains entails certain assumptions. One belief is that within each domain there exists a series of steps or stages, ranging from the level of rank novice, through apprentice or journeyman's status, to the status of expert or master. Irrespective of domains, there should (in proper Piagetian fashion) be a stagelike sequence through which any individual must pass. However, individuals differ greatly from one another in the speed with which they pass through these domains; and, *contra* Piaget, success at negotiating one domain entails no necessary correlation with speed or success in negotiating other domains. Domains may be cordoned off from one another in this sense. Moreover, progress in a domain does not depend entirely on the solitary individual's actions within his world. Rather, much of the information about the domain is better thought of as contained within the culture itself, for it is the culture that defines the stages and fixes the limits of individual achievement. One must conceive of the individual *and* his culture as embodying a certain stage sequence, with much of the information essential for development inhering in the culture itself rather than simply inside the individual's skull.

This focus on an individual's progress through a domain has stimulated Feldman to confront the phenomenon of the child prodigy. The prodigy may be thought of as an individual who passes through one or more domains with tremendous rapidity, exhibiting a speed that seems to render him qualitatively different from other individuals. In Feldman's view, the mere existence of a prodigy represents a remarkable "co-incidence" of a number of factors—among them an initial, possibly inborn proclivity, considerable pressure from parents and family, excellent teachers, high motivation, and, perhaps most important, a culture in which that proclivity will have a chance to flower. In monitoring the prodigy as he advances, one glimpses a "fast-forward" picture of what is involved in all educational processes. Unlike the Piagetian individual advancing chiefly by himself along a path available to humans the world over, the prodigy is a fascinating amalgam of the highest amounts of natural proclivity with the greatest amounts of stimulation and structure as provided by his own society.

A concern with prodigies well illustrates certain central features of this new approach to intellectual development. First of all, the very existence of prodigies poses a problem that cannot be handled by Piagetian theory:

how an individual can be precocious in just one area of development. (I might note parenthetically that none of the other approaches reviewed here can deal adequately with prodigious behavior either.) Second, a survey of prodigies provides support for the notion of particular symbolic domains, since prodigious behavior is characteristically found in certain domains (mathematics, chess playing) while rarely if ever in other ones (literary skill). Study of prodigious achievement also provides support for the Piagetian belief in specific stage sequences, since the progress of prodigies can be well described in terms of negotiation of a set of steps or stages. And, because prodigious accomplishment is not possible without extensive environmental support, focus on the prodigy also highlights the contributions of the society. Finally, through attention to unusual populations like prodigies, investigators of various forms of intelligence have the opportunity to probe the nature and the operation of certain intellectual competences in pristine form.

Not surprisingly, each of the aforementioned researchers working in the symbol systems tradition exhibits a somewhat different focus. For instance, Gavriel Salomon, an educational psychologist working in Israel, has focused particularly on the media of transmission: he studies the *modus operandi* of television, books, and film and the ways in which the various symbol systems of the cultures are picked up and transmitted by these media. Moreover, he has tackled the question of which "prostheses" might enable individuals to acquire information more readily from the various media. David Olson, a cognitive developmental psychologist at the Ontario Institute for Studies on Education, pioneered in this area by showing that even in a task as simple as constructing a diagonal, the medium of presentation exerts a profound influence on a child's performance. Recently, Olson has focused more on the role of the symbol systems of literacy. He has accrued evidence that individuals reared in a society where literacy is highlighted learn (and reason) differently from those who employ other kinds of symbol systems in nonschooled settings.

In work at Harvard Project Zero, my colleagues and I have sought to uncover the fine structure of development within each particular symbol system. We have sought to ascertain whether certain common processes may cut across diverse symbol systems, or whether, alternatively, each symbol system is better described as having its own developmental course. Then, in complementary research at the Boston Veterans Administration Medical Center, my colleagues and I posed the opposite question. In which ways do the various human symbolic capacities break down under specific conditions of brain damage? Drawing on information from the developmental and the neuropsychological perspectives, we have striven to arrive at a more satisfactory notion of the structure and organization of human symbolic functioning. Our goal has been to arrive at the "natural kinds" of symbol systems: the families of symbol systems that hang together (or fall apart), and the ways they might be represented in the human nervous system.

To my mind (and here I do not presume to speak for others in the symbol systems movement), a pivotal issue concerns the definition and delineation of particular symbolic domains. Proceeding in terms of logical considerations, one can effect discriminations among specific symbol systems. This is what Nelson Goodman and other philosophers have elected to do. One can also adopt a historical or a cultural view, simply taking as given the list of particular symbol systems or domains that a culture has chosen to exploit for educational or communicational purposes. Following this line of argument, one refers to map making or chess playing, history or geography, as domains, just because they have been so designated by the culture as a whole. One can also adopt the empirically ordered approach of intelligence testers: here one simply ascertains which symbolic tasks correlate statistically, and assumes that these reflect the same underlying competence. In following this path, one is restricted by the nature of the tasks used. Hence, one may well come up with a misleading correlation, particularly if one happens to have used an idiosyncratic collection of tasks.

Finally, one can assume the approach of the neuropsychologist, who looks at which symbolic capacities break down together under conditions of brain damage, and hypothesizes that these reflect the same natural kind. Even this approach (to which I am personally wedded) has its pitfalls, however. For one thing, physical proximity in the nervous system may not reflect similar neural mechanisms. Highly different functions might be carried out in neighboring regions of the cortex. For another, the way in which cultures "mold" or "exploit" raw computational capacities may influence the organization of capacities; and it may be the case that across different cultures, one encounters different patterns of breakdown—as happens, for example, when cultures have evolved radically different forms of reading, one involving pictographs, another based upon character-sound correspondence. The lesion that causes reading disturbance in one culture (say, Italy) produces no disturbance in a culture where reading proceeds by a different mechanism (say, Japan).

There are other difficulties with a neuropsychological approach. Even though breakdowns provide valuable insight into organization of intact capacities, one cannot blithely assume that breakdown directly unmasks organization. The ways a radio breaks down (for example, through destruction of a plug) do not necessarily tell you how best to describe the ordinary operation of the radio. After all, while you can stop the radio by pulling out the plug, this information is irrelevant for understanding the actual mechanical and electrical workings of the apparatus.

In view of these and other limitations in each "window" upon symbolic functioning, I have taken a determinedly catholic approach in what follows. I have surveyed information from a wide range of sources—including developmental data, psychometric findings, descriptions of special populations, such as idiots savants and prodigies—all in an effort to arrive at an optimal description of each domain of cognition and symbolization. Nonetheless, every researcher has a bias; and in my own case, I believe that the most valuable (and least misleading) information is likely to come from a deep knowledge of the nervous system: how it is organized, how it develops, how it breaks down. Findings from the brain, in my view, serve as the court of last resort, the ultimate arbiter among competing accounts of cognition. Therefore, before embarking upon my study of different intelligences, I shall survey some relevant highlights of recent work in the biological sciences.

3

Biological Foundations of Intelligence

The Phenomena to Be Explained

A comprehensive science of life must account for the nature, as well as the variety, of human intellectual competences. In view of the spectacular progress of recent decades in such areas as biochemistry, genetics, and neurophysiology, there is every reason to believe that the biological sciences will eventually be able to offer a cogent account of these intellectual phenomena. Indeed, it is high time that our understanding of human intellect be informed by the findings that have accrued in the biological sciences since the time of Franz Joseph Gall. And yet, because psychologists and biologists inhabit different environments, the task of marshaling biology to explain human intelligence has barely begun.

As I read current findings in the brain and biological sciences, they bear with particular force on two issues that concern us here. The first issue involves the *flexibility of human development*. The principal tension here centers on the extent to which the intellectual potentials or capacities of an individual or a group can be altered by various interventions. From one point of view, development may be viewed as relatively locked-in, preordained, alterable only in particulars. From an opposing perspective, there is far more malleability or plasticity in development, with appropriate interventions at crucial times yielding an organism with a far different range and depth of capacities (and limitations). Also pertinent to the issue of flexibility are the related questions of the kinds of intervention that are most effective, their timing, and the role of critical periods during which pivotal alterations can be brought about. Only if such issues are resolved will it be possible to determine which educational interventions are most effective in allowing individuals to achieve their full intellectual potentials.

The second issue is the *identity*, or *nature*, *of the intellectual capacities* that human beings can develop. From one point of view, which I associated earlier with the hedgehog, human beings possess extremely general powers, all-purpose information-processing mechanisms that can be put to a large, or perhaps even an infinite, number of uses. From an opposite perspective, that more reminiscent of the fox, human beings (like other species) have a proclivity to execute certain specifiable intellectual operations while proving incapable of performing other intellectual operations. An allied issue concerns the extent to which different portions of the nervous system are, in fact, committed to carrying out particular intellectual functions, as opposed to being available for a wide range of operations. It proves possible to analyze this issue of identity at various levels, ranging from the functions of specific cells, at one extreme, to the functions of each half of the brain, on the other. Finally, as part of this concern with identity, the biologist needs to account for those capacities (like language) that seem to evolve to a high degree in all normal individuals, as against other capacities (like music) where striking differences in individual achievement are far more prevalent.

Taken together, these sets of questions add up to a search for general principles that govern the nature and the development of human intellectual capacities, and that determine how these are organized, tapped, and transformed over a lifetime. Much current work in the biological sciences strikes me as relevant to these issues, though often it has not been conceived along these lines. Here I attempt to mine those lodes of research that seem most relevant to a student of the human mind.

In my view, the preponderance of evidence points to the following conclusions. There is considerable plasticity and flexibility in human growth, especially during the early months of life. Still, even that plasticity is modulated by strong genetic constraints that operate from the beginning and that guide development along some paths rather than along others. As for the issue of identity, evidence is accumulating that human beings are predisposed to carry out certain specific intellectual operations whose nature can be inferred from careful observation and experimentation. Educational efforts must build upon a knowledge of these intellectual proclivities and their points of maximum flexibility and adaptability.

These, then, are some conclusions at which one may arrive after weighing the relevant biological evidence. For individuals already familiar with the findings of the biological sciences, as well as for those who have little tolerance for reports from the "harder" sciences, it is possible at this point in the narrative to move directly to Chapter 4, where I introduce the criteria for an intelligence. Those with an interest in the details that undergird the foregoing conclusions are invited to enter the realm of genetics.

Lessons from Genetics

Once one has elected to peer through the biologist's lens, an initial concern with genetics is virtually inevitable (and certainly proper). Moreover, given the incredible strides made in genetics, since the "code was cracked" by James Watson and Francis Crick some thirty years ago, it is not surprising that psychologists have searched—in the composition of DNA, RNA, and their fascinating interaction—for *the* answer to puzzles about intellect. Unfortunately, however, lessons from this line of study are far from direct.

To be sure, the geneticists' discoveries must form the point of departure for any biological study. After all, we are living organisms; and, in one sense, everything that we will ever achieve has been coded in our genetic material. Moreover, the distinction between the genotype—the organism's makeup as determined by the genetic contributions of each parent—and the phenotype—the organism's observable characteristics as expressed within a given environment—is fundamental to consideration of any individual's behavioral and intellectual profile. Equally fundamental is the notion of variation: because of the huge number of genes contributed by each parent and the innumerable ways in which they can be combined, we need not worry that any two individuals (except identical twins) will unduly resemble one another, or that any two individuals will exhibit identical profiles.

Genetics has made its greatest progress in accounting for simple traits in simple organisms. We know a great deal about the genetic basis for structures and behaviors in the fruit fly; and through studies of inheritance patterns, we have gained insight into the transmission of specific human pathologies like sickle cell anemia, hemophilia, and colorblindness. But when it comes to more complex human abilities—the capacities to solve equations, to appreciate or create music, to master languages—we are still woefully ignorant about the genetic component and its phenotypical expression. First of all, these abilities cannot be studied experimentally in the laboratory. Furthermore, rather than being related to a specific gene or a small set of genes, any complex trait reflects many genes, a fair number of which will be polymorphic (allowing a number of different realizations across a range of environments). Indeed, when it comes to capacities as broad (and vague) as human intelligences, it is questionable whether one ought to speak of "traits" at all.

Those scholars of a geneticist bent have, of course, speculated about what a talent might be. According to one such account certain combinations of genes may be correlated with one another, and these in turn may cause the production of enzymes that affect specific structures in one region of the brain. As a result of enzyme action, these structures might become larger, feature more connections, or promote more inhibition, any one of which possibilities might culminate in a greater potential for high achievement. But the very fact that these speculations involve so many hypothetical steps indicates how far they are from being established facts. We do not even know whether those individuals who have a talent (or, for that matter, a glaring defect) reflect an inherited tendency to form certain neural connections (which would then be found in others who are closely related) or whether they simply represent one tail of a randomly generated distribution (in which case they could equally well arise in any two unrelated individuals).

Probably the most reliable clues to the genetics of human talents come from studies of twins. By comparing identical twins with fraternal twins, or identical twins reared apart with those reared together, we can gain some purchase on which traits are most subject to hereditary influences. Still, scientists eyeing the same set of data—and not even disputing the data—can reach widely divergent conclusions about heritability. Simply on the basis of certain mathematical and scientific assumptions, some scientists would place the heritability of intelligence (as measured by IQ tests) as high as 80 percent. In other words, these authorities would claim that up to 80 percent of the variability in intelligence scores in that population can be ascribed to one's genetic background. Other scientists pondering the same data but operating on different assumptions would estimate heritability as less than 20 percent or even zero. Naturally, most estimates run somewhere in between, with 30 percent to 50 percent being commonly cited. There is considerable agreement that physical traits are most straightforwardly genetic, that aspects of temperament are also largely genetic; but that when one comes to aspects of cognitive style or personality, the case for high heritability is far less convincing.

The genetic literature provides few unequivocal answers to questions that preoccupy a student of intelligence. Nonetheless, there are useful concepts that might inform our investigation. Let's begin with the well-documented fact that, as a result of their genetic makeup, certain individuals are "at risk" for a given disease (like hemophilia) or neurological condition (like severe retardation). This fact does not in itself certify that they will get the disease; factors of probability as well as accidents of environment or special treatment also play their role. This fact suggests only that, other things being equal, these individuals are more likely to contract the disease than is someone without this hereditary disposition.

By analogy, it may be useful to consider certain individuals as "at promise" for the flowering of a certain talent. Again, this diagnosis does not ensure that they will develop the talent: one will not become a great chess player, or even a "patzer," in the absence of a chess board. But given an environment where chess is played, and some stimulation, individuals of promise have a special proclivity for acquiring the skill rapidly and reaching a high level of competence. Being at promise is a *sine qua non* for becoming a prodigy; even so, thanks to certain "hot house" training methods, such as the Suzuki Violin Talent Education Program, even an individual with apparently modest genetic promise may make remarkable strides in a short time.

Another suggestive line of speculation concerns the variety of traits and behavior of which human beings are capable. In a large and heterogeneous population like ours, with considerable intermarriage, one encounters a wide variety of traits; but over time, extreme traits tend to become invisible or to disappear altogether. In contrast, certain populations (for example, those in isolated South Sea islands) have lived as a single group for thousands of years and have avoided any kind of intermingling with other groups. These latter populations will exhibit *genetic drift:* through processes of natural selection, they will come to possess a genetic pool that may be distinctly different from that of other populations.

It is not always possible to separate out the purely genetic factors from those reflecting an unusual natural environment or an exotic cultural system. Yet, according to the virologist Carleton Gajdusek, who has studied many primitive societies, populations subjected to genetic drift often exhibit a remarkable set of characteristics, including unusual diseases, immunities, physical traits, behavioral patterns, and customs. It becomes crucial to record these factors before they disappear, or become invisible, owing to the demise of the group or to its extensive intermingling with other populations. Only by careful documentation of these groups will it become possible to determine the full range of human abilities. Indeed, once these groups have disappeared, we may not even be able to envision that they could have been capable of the actions, skills, or traits that they in fact exhibited. But once we have established that some group—in fact, that any human being—has exhibited a certain competence, we can look for—and attempt to foster—that capacity in other members of the species—our species. (An opposite course can be pursued in the case of undesirable traits or competences.) To be sure, we can never definitely establish that a given trait has a genetic component, but that determination actually proves irrelevant to our present concern: documentation of the varieties of human nature.

Consider this perspective in another way. Our genetic heritage is so variegated that one can postulate all kinds of abilities and skills (as well as maladies and infirmities) that have not yet emerged, or that we have not yet come to know about. Given genetic engineering, countless other possibilities arise as well. An individual with a clever imagination might well be able to anticipate some of these possibilities. However, it is a far more prudent research strategy to sample widely among human beings of diverse stock and to determine which competences they have in fact achieved. Studies of remote and isolated groups—the prize for the geneticist—prove extremely valuable for psychologists as well. The broader the sampling of human beings, the more likely that any list of the range of human intelligences will be comprehensive and accurate.

The Neurobiological Perspective

While genetics still proves to be of limited utility for the student of intelligence, a review of neurobiology—including the specialties of neuroanatomy, neurophysiology, and neuropsychology—promises to bear much richer fruit. Knowledge of the nervous system is accumulating as rapidly as knowledge of genetics, and the findings are much closer, so to speak, to phenomena of cognition and the mind.

Canalization Versus Plasticity

A study of neurobiology bears critically on the two central issues with which I am concerned in this chapter. We can ferret out general principles, as well as specific nuances, concerning the flexibility of development and the identity of human competences. In this survey, I shall begin by considering the issue of flexibility, and particularly those findings that document the relative plasticity of the nervous system during the early phases of development. Following the review of flexibility, I shall turn to those lines of research that help illuminate the abilities and operations of which human beings are capable. Though my concern throughout this volume will fall on the capacities of human beings, and the extent to which they can be developed and educated through appropriate interventions, most of the findings that I review will, in fact, be drawn from research with animals—invertebrates as well as vertebrates. And in this effort, I have been helped in particular by two lines of work that have deepened our understanding of the principles of development: the work of David Hubel, Torsten Wiesel, and their co-workers on the development of the visual system in mammals; and the works of Fernando Notebohm, Peter Marler, Mark Konishi, and their co-workers on the development of singing capacities in birds. While the transfer from animal to human populations must be made cautiously, particularly in the intellectual realm, findings in these areas are far too suggestive to be ignored.

A key concept for the understanding of neural growth and development is *canalization*. First posited by C. H. Waddington, a geneticist at Edinburgh University, canalization refers to the tendency of any organic system (like the nervous system) to follow certain developmental paths rather than others. Indeed, the nervous system grows in an exquisitely timed and elegantly programmed fashion. The origins of cells in the fledgling neural tube, and their migration to regions where they will eventually constitute the brain and spinal chord, can be observed with predictable regularity within and, to some extent, even across species. Far from representing a random or accidental collection, the neural connections that are actually effected reflect the highest degree of biochemical control. One beholds a stunning epigenetic sequence where each step in the process lays the groundwork for, and facilitates the unfolding of, the next.

To be sure, the development of any system also reflects environmental influences: if, through experimental intervention, one alters the chemical balance, one can affect the migration of particular cells or even cause one cell to carry out the function ordinarily assumed by another. Yet according to Waddington, it proves surprisingly difficult to divert such patterns from what appears to be their prescribed developmental goals—in the present case, an adequately functioning nervous system. As Waddington put it, "it is quite difficult to persuade the developing system not to finish up by producing its normal end result." Even if one seeks to block or otherwise to divert the expected patterns, the organism will tend to find a way to finish up in its "normal" status; if thwarted, it will not return to its point of origin but will rather make its peace at a later point in the developmental course.

So far my description of the development of the nervous system has stressed strict, genetically programmed mechanisms. This is appropriate. And yet an equally amazing facet of biological development is its flexibility, or, to adopt the more technical epithet, its *plasticity*. An organism exhibits plasticity in a number of ways. To begin with, there are certain developmental periods where a relatively wide range of environments can each bring about the proper effects. (For example, if a human infant is swaddled for most of the first year of life, it will still walk normally during the second year.) Moreover, in the event that the young organism is deprived or damaged in a significant way, it may often exhibit great recuperative powers. Indeed, in general, this plasticity proves greater at the earliest points in development. For example, even if a human infant loses the dominant of its two cerebral hemispheres, it will still learn to speak. But there is a point at which the Rubicon is crossed, and plasticity is permanently on the wane. The adolescent or the adult who loses a hemisphere will be severely impaired.

Yet even these generalizations about plasticity must be qualified. First of all, sometimes early injury or deprivation can have extremely severe results (e.g., failure to use one eye during the first months of life infirms the possibility of binocular vision). Second, certain abilities or skills prove robust, even in the face of an adult injury, thus suggesting a residual plasticity that endures throughout much of the life cycle. Some adults recover the ability to talk despite massive injury to the left (or dominant) hemisphere of the brain, and many recover the use of paralyzed limbs. Overall, the notion of plasticity cannot be considered apart from the timing of a particular manipulation or intervention and from the nature of the behavioral competence involved.

Plasticity is limited in other ways as well. Reflecting their behaviorist heritage, some psychologists have been prone to assume that most any organism can, given proper training, learn to do most anything. Searches for "horizontal" "Laws of Learning" have often reflected this faith. Similar claims have been made about human beings, such as the suggestion that anything can be learned at any age, in some useful form. More recent studies have come down, however, in harsh opposition to this optimistic cast of mind. An emerging consensus insists that each species—including ours—is specially "prepared" to acquire certain kinds of information, even as it proves extremely difficult, if not impossible, for that organism to master other kinds of information.

A few examples of this preparedness and counter preparedness will be helpful. We know that many birds are capable of learning songs, and some can eventually produce a great variety of songs. And yet female sparrows may be so carefully "pretuned" that they are sensitive only to the particular dialect sung by males in their own region. Rats can learn very quickly to run or jump to escape shock but only with greatest difficulty to press a lever in order to effect the same escape. Moreover, there are even limitations to the jumping mechanism. While jumping to avoid a shock seems to be a natural or "prepared" response, if the rat must jump in a box with a closed lid, learning will be extremely slow. The ease with which all normal (and many subnormal) individuals master natural language (despite its apparent complexity) suggests that the species as a whole is specially prepared to acquire facility in this realm. By the same token, the difficulties most humans exhibit in learning to reason logically—particularly when propositions are presented in an abstract form—suggests no special preparedness in this area and perhaps even a predisposition to attend to the concrete specifics of a situation rather than to its purely logical implications. While no one understands the reasons for selective preparedness, it may be that certain neural centers can be readily triggered, stimulated, programmed, and/or inhibited while others prove far more difficult to activate or inhibit.

In the light of these general remarks about plasticity in behavior, we are now in a position to look more closely at evidence pertaining to the degree of determinedness (or flexibility) that characterizes the developing organism. Our survey will consider the particulars of plasticity around the time of birth, the effects of various early experiences on subsequent development, and the possibility that various kinds of learning can be understood at the neurological or the biochemical level.

Principles of Plasticity During Early Life. While the particulars concerning each species differ, research on plasticity in early life has yielded a number of principles that seem reasonably robust. A first principle enunciates the maximum flexibility encountered early in life. Consider one example, which can stand for many others in the literature. As explained by W. Maxwell Cowan, neurobiologist at the Salk Institute, both the forebrain and the neural part of the eye develop out of the head end of the neural plate. If, at an early stage in development, one removes a small piece of ectodermal tissue, neighboring cells proliferate, and the development of both the brain and the eye should proceed normally. But if the same operation is performed a little later, there is a permanent defect either in the forebrain or in the eye; the actual damage depends on the particular piece of tissue that has been removed. Such progressive "blocking out" leads to the determination of increasingly precise regions of the brain. Studies by other neurobiologists, such as Patricia Goldman, confirm that during the earliest period of life, the nervous system can adapt flexibly to severe injury or experimental alteration. For some time thereafter, the nervous system may devise an alternative route or connection that may prove adequate; but if the injury or alteration occurs too late during the developmental process, the relevant cells will either connect randomly or atrophy altogether.

A second related principle underscores the importance of so-called critical periods during the process of development. For example, in the cat, there is a critical period in visual development from the third to the fifth postnatal week. If, during this time, one eye is deprived of form or light, then the central connections of the eye change and the ill-seeing eye will be suppressed from functioning. Such interference seems to be permanent. As a general point, it seems that the most vulnerable time for an organism occurs during these sensitive periods. Irreversible damage to the central nervous system seems particularly likely to occur in the wake of even mild restrictions during such a critical period. Conversely, rapid development will occur if the proper conditions are obtained during the critical period.

According to a third principle, the degree of flexibility differs across the region of the nervous system with which one is concerned. Regions that develop later in childhood, such as the frontal lobes or the corpus callosum, turn out to be more malleable than those that have developed in the first days and weeks of life, such as a primary sensory cortex. The surprising degree of *uncommittedness* that characterizes regions like the corpus callosum seems to reflect both the need for a high degree of modifiability for certain cortical connections and the importance of specific postnatal experiences in determining the kinds of connection that will ultimately be made. Indeed, when it comes to the most complex of human capacities, such as language, the individual can withstand even massive damage, including the removal of an entire hemisphere, during the first few years of life and still acquire the ability to speak in a reasonably normal fashion: this recovery suggests that large portions of the cortex remain uncommitted (and thus available for diverse uses) during early childhood.

A fourth principle concerns those factors that mediate or modulate development. An organism will fail to develop normally unless it undergoes certain experiences. Thus, the cat's visual system will not develop normally—and parts of it will actually atrophy—if the animal is not exposed to patterned light after birth. Moreover, the cat must be exposed to a variegated environment, permitted to use both eyes, and move about its environment. If exposed to horizontal patterns only, the cells destined to carry out vertical processing will either atrophy or be taken over for other functions. If the cat is allowed to use only one eye, those cells dedicated to binocular vision will degenerate. And if the cat does not move actively in its environment—for example, if it is passively transported through a patterned environment—it will also fail to develop a normal visual system. It seems that the neural system that mediates vision exhibits a scheduled plan for development that "expects" visual inputs of certain sorts during sensitive periods. If proper stimulation is lacking, or if inappropriate stimulation is supplied, the usual developmental goals will not be achieved, and the animal will fail to function properly in its environment.

A final principle treats the long-term effects of injury to the nervous system. While some injuries exert immediate and evident effects, others may be invisible at first. Suppose, for example, that a region of the brain that is destined later in development to assume an important function happens to be injured at an early point in life. It may well be that the consequences of the injury will not be observed for some time. Thus, injuries to the frontal lobes in primates may not be detected during the first years of life but may become all too manifest at a later time when the animal is expected to carry out those complex and organized forms of behavior that are ordinarily mediated by the frontal lobes. Early brain injury may also stimulate certain anatomical reorganizations that ultimately prove counterproductive. For instance, connections may be formed that allow the animal to carry out tasks crucial at the present time but that prove useless for the emergence of needed skills at a later time. In such cases, the tendency of the nervous system to canalize may actually have maladaptive long-term consequences.

Consideration of these five principles should confirm that any simple verdict on the issue of determination versus flexibility is impossible. Strong pressures favor each factor, and both therefore exert considerable influence on the development of the young organism. Determination (or canalization) helps to ensure that most organisms will be able to carry out the functions of the species in the normal way; flexibility (or plasticity) allows for adaptability to changing circumstances, including anomalous environments or early injuries. Clearly, if one must sustain an injury, it is better to have it early; but probably every deviation from the normal developmental path exacts its cost.

Early Experience. Up to this point, I have considered chiefly the effects of specific kinds of experience (such as exposure to certain kinds of stripes) upon relatively circumscribed regions of the brain (most notably, the visual system). But psychologists and neurologists have also examined the question of more general effects of stimulation, or deprivation, on the overall functioning of organisms.

Pioneering studies come from Mark Rosenzweig and his colleagues at the University of California at Berkeley. Beginning in the early 1960s, the Rosenzweig group raised animals (chiefly rats) in environments that were enriched: these environments featured numerous other rats as well as various toys, such as ladders and wheels. A comparable set of rats were raised in an "impoverished environment," which contained enough food but no special features. The "enriched rats" performed better on various behavioral tasks and were also trimmer than their well-fed but duller peers. After eighty days in these contrasting environments, all the rats were sacrificed and their brains subjected to analysis. The crucial findings: the cerebral cortexes of the enriched rats weighed 4 percent more than the cortexes of the impoverished (though fatter) rats. More crucially, the largest increase in brain weight occurred in those portions of the brain that serve visual perception, presumably the portions that had been particularly stimulated in the enriched environment.

Numerous studies with rats and other species have confirmed that an enriched environment produces more elaborate behavior as well as palpable changes in brain size. Effects can be surprisingly specific. The Rosenzweig team has shown that if you provide a richer experience to only one half of the brain, only that half exhibits changes in cell structure. William Greenough has demonstrated that in animals raised in complex environments, one finds larger nerve cells in some brain areas, as well as more synapses, synaptic connections, and other dendritic connections. As he summarizes it, "the gross regional size changes that accompany differences in experience are associated with changes at the neuronal level in the number, pattern, and qualities of synaptic connections."

Other intriguing and highly specific brain changes have been claimed. As part of his studies of the songs of male canaries, Fernando Nottebohm has correlated the size of two nuclei in the bird's brain with the appearance of singing. He finds that during the most productive vocal periods, these two nuclei may become double the size they reach during the least productive period, during the summer molt. Then, when the brain grows larger in the fall, new nerve fibers develop, fresh synapses are formed, and accordingly, a larger song repertoire once again emerges. Apparently, in birds, the learning (or relearning) of a motor activity translates directly into the size of the relevant nuclei, the number of neurons, and the extent of connections among them.

To my knowledge, scientists have hesitated to speculate in print about similar changes in brain size accompanying (or causing) the diverse ability profiles in human beings. In the absence of suitable experimental methods, such prudence seems proper. But it is worth citing the observation of two talented neuroanatomists, O. and A. Vogt. For many years, the Vogts conducted neuroanatomical studies of the brains of many individuals, including talented artists. One painter whose brain they observed turned out to have a very large fourth layer of cells in his visual cortex; and a musician with perfect pitch from early childhood had an analogously large region of cells in his auditory cortex. As hypotheses of this sort become more respectable, and as noninvasive methods for studying brain size, shape, and processing routes become more widely utilized, I would not be surprised to find contemporary support for these ancient phrenological themes.

But bigger is not always better, and vast numbers of cells or fibers are not always virtues in themselves. Indeed, one of the most fascinating findings of recent years in neurobiology supports this cautionary note. Initially, the nervous system produces a great excess of neuronal fibers; a significant portion of the developmental process involves the pruning, or atrophying, of excessive connections that do not appear to be necessary and may, in fact, be injurious to normal function. The most critical interpretations along these lines have been made by two French scientists, Jean-Pierre Changeux and Antoine Danchin. These researchers have noted that in diverse regions of the brain, there are many more neurons initially than will eventually survive. A period of "selective cell death" occurs, usually at about the time when the population of neurons are forming synaptic connections with their designated targets. The death may involve anywhere from 15 percent to 85 percent of the initial neuronal population.

Why should there be a large excess of initial connections, and why should certain connections endure while others atrophy? There is speculation that early excessive "sprouting" reflects (or better, constitutes) the flexibility of the period of growth. This normal feature of development also has adaptive advantages. If some damage occurs during a time when excessive connections are available, the chances are greater that the organism will survive despite injury. In support of this notion, a tremendous growth in cell connections occurs immediately after a lesion, with sometimes as much as six weeks' worth of growth occurring in seventy-two hours. Analogously, if one eye is removed at birth, the death of retinal ganglion cells, which would ordinarily occur in the first two postnatal weeks, is markedly reduced.

There are other possible reasons for this proliferation of cell processes and synapses. During this period of richness, there appears to be intense competition among the cells, with those that are most effective in forming connections of the appropriate strength and specificity proving most likely to survive. Perhaps, in time-honored Darwinian fashion, this proliferation may entail a kind of competition, allowing the most fit or appropriate of the organism's nerve fibers to prevail.

An excess of nerve fibers in early development may well lead to the transient appearance of functional and behavioral properties associated with the excess connections. And here one may encounter U-shaped phenomena, where the behavior of the immature organism (the left arm of the U) bears a striking resemblance to behavior ordinarily found only among adult organisms (the right arm of the U). Quite possibly, certain early reflexes in humans—like swimming or walking—reflect a proliferation of connections that temporarily allow certain precocious behavior. It is also possible that the tremendously rapid learning of which young organisms are capable, particularly during certain critical periods, may be related to an excess of connections, some of which will soon be pruned or eliminated. For instance, in human beings, the density of synapses increases sharply during the first months of life, reaches a maximum at the ages of one to two (roughly 50 percent above the adult mean density), declines between the ages of two and sixteen, and then remains relatively constant until the age of seventy-two. More than one scientist has speculated that the extremely rapid learning of the young child (for example, in the area of language) may reflect an exploitation of the large number of synapses available at that time.

And after the pruning has occurred? We may have here a functional definition of maturity—that time when excess cells have been eliminated and the originally targeted connections have been effected. The flexibility of youth seems at an end. Through survival of the fittest, the number of neurons has now been adjusted to match the size of the field that they are designed to innervate. (If a new target like an extra limb is surgically added, the number of neurons will not decline as precipitously; there is now additional space in which the synapses can be formed.) The critical period apparently ends when the process of synapse elimination has progressed to the point where few, if any, synapses are still capable of competitive interaction. Most scientists feel that there are further neural changes later in life. But, whether with aging there is a gradual decline in synaptic density, progressive reduction in dendritic length and branching, or a more selective loss (being restricted to certain areas of the cortex) is an issue on which scientists are not yet agreed.

Biological Bases of Learning. Understandably, most neurobiological research with implications for human beings has been conducted with primates;

and there has been a focus on the principal sensory systems, which presumably work similarly across the biological order. But recently there have been efforts to understand the basis of learning, using species quite remote from man. Because of the suggestiveness of the findings, I quote two samples here.

In my view, a veritable treasure trove of information that has stimulated the thinking of cognitively oriented scholars has been obtained by students of bird song. Although from a different order of animals, bird song involves highly complex activities, which, as it happens, are lateralized to the left portion of the bird's brain and are all mastered in instructive ways during the juvenile period.

In the face of many differences across bird species, a few generalizations seem warranted. Early in the first year of life, the male bird produces a *subsong*—a babbling output that continues for several weeks. This is followed by the period of *plastic song*, a longer interval, where the bird rehearses a large number of the bits of those songs that it will eventually use to communicate its territory to other birds and also to advertise for a mate. This playful rehearsal resembles the exploratory activities exhibited by primates in many realms of activity.

Where avian species differ from one another is in the flexibility and the conditions of song learning. Some birds, like the ringdove, will come to sing the song of their species eventually, even in the absence of exposure to the correct model. Some birds, like canaries, require feedback from their own singing, but not exposure to a model. (If such birds are deafened, they fail to master their species' repertoire.) And other birds, like the chaffinch, require exposure to the models supplied by conspecifics, in order to sing an appropriate song. Some birds sing the same songs each year, while others alter their repertoire on an annual basis. (It is clearly vital to understand the biological underpinnings of these "cultural" differences.) But what is striking is that the bird emits during learning far more songs and song bits than it will vocalize during its adult prime. Moreover, birds are oriented to favor the songs from the environment that their species is destined to learn, and (relatively speaking) to ignore songs from other species or even other dialects of their own species.

As I have already noted, the production of song depends upon structures in the left portion of the bird's nervous system. Lesions there prove far more disruptive than lesions in matching areas of the right brain. One can, in fact, produce an aphasia—or amusia—in birds. But the aphasic canary can recover its prior songs because the homologous pathways of the right hemisphere have the potential of being exploited. In this recovery of function, birds are more fortunate than adult humans.

The learning of bird songs provides one intriguing model for how organisms come to master a highly particular kind of skill through the interplay of environmental stimulation, exploratory practice, and a predisposition to develop certain structures of the nervous system. In my view, it may well prove possible some day to apply some of the principles involved in the learning of bird song to the processes whereby higher organisms (including human beings) come to master the cognitive and symbolic systems of their own cultural milieu. Another quite divergent set of researches, using a simple mollusk called *Aplysia Californica*, promises to cast additional light on the biological bases of learning.

With his colleagues, Eric Kandel of Columbia University has been examining the simplest forms of learning in *Aplysia*. He has been investigating how this organism, with a relatively small number of neurons, becomes able to habituate to a stimulus (so that it no longer responds after a while), becomes sensitized to a stimulus (so that it can respond even in the presence of diminished stimulation), and becomes classically conditioned (so that it can respond to a learned, or conditioned, stimulus as well as to an unconditioned, or reflexive, stimulus). And he has come up with four major principles.

First of all, elementary aspects of learning are not diffusely distributed in the brain but can rather be localized in the activity of specific nerve cells. Some learned behavior may involve as few as fifty neurons. Second, learning results from an alteration in the synaptic connections between cells: rather than necessarily entailing new synaptic connections, learning and memory customarily result from alteration in the strength of already existing contacts. Third, prolonged and profound changes in synaptic strength can come about through an alteration in the amount of chemical transmitter released at the terminals of neurones—the sites at which cells communicate with other cells. And so, for example, in the course of habituation, each action potential produces progressively less influx of calcium and, hence, less transmitter release than does the preceding action potential. Finally, these simple processes of altering synaptic strengths can be combined to explain how progressively more complex mental processes take place, and thus yield, in Kandel's phrase, a "cellular grammar" underlying various forms of learning. That is, the same processes that explain the simplest form of habituation serve as a kind of alphabet from which one can compose far more complex forms of learning, such as classical conditioning. As Kandel summarizes his findings:

> Basic forms of learning, habituation, sensitization, and classical conditioning *select* among a large repertory of pre-existing connections and alter the strength of a subset of this repertory. . . . An implication of this view is that the potentialities for many behaviors of which an organism is capable are built into the basic scaffolding of the brain and are to that extent under genetic and developmental control. . . . Environmental factors and learning bring out these latent capabilities by altering the effectiveness of the pre-existing pathways, thereby leading to the expression of new patterns of behavior.

Thanks to Kandel and the lowly mollusk, some of the major forms of learning investigated by psychologists can be described in terms of events occurring at the cellular level, even including certain candidate chemical transactions. The once seemingly unbridgeable gap between behavior and biology seems to have been sealed. The work of Kandel and his associates also casts tantalizing light on those issues of the specifiability of particular competences, which will concern us in the following pages. It seems that the same principles may characterize all neural cells, independent of species membership or form of learning—apparent support for a "horizontal" view of learning. And yet, as Kandel indicates, organisms themselves seem capable of only certain patterns of behavior and not others; and this phenomenon will also have to be accounted for in any biological approach to cognition.

In contrast to the state of affairs in genetics, where links between the mainstream of the science and issues of human cognition were few and speculative, the view from neurobiology has proved far more revealing for our enterprise. Clear principles of plasticity and flexibility, determination and canalization have been uncovered. There is good reason to believe that, with suitable modifications, these principles can apply to the ways in which human beings develop certain cognitive systems, and learn to achieve certain intellectual skills, in the process of following certain paths rather than others. The clear and manifest effects of rich (or impoverished) early experiences on the general functioning of the organism have also been convincingly demonstrated. And we already know from studies of the effects of malnutrition in human beings that analogous effects can occur in our own species, with deleterious consequences for both emotional and cognitive functioning. Finally, through studies of such unlikely populations as song birds and California mollusks, we have received promising insights into the ways in which forms of learning are manifest at the nervous system, cellular, and biochemical levels. While there is still an enormous distance between these simple forms of behavior and the varieties of learning and development of greatest moment to human beings, at least some of the insights gained from these lines of study should eventually prove applicable to the investigation of human learning and mastery.

Identifying the Elements of the Nervous System

Up to this point, I have at times tolerated a convenient fiction: the contention that the nervous system is relatively undifferentiated, and that variation in size, density, and connectivity can be discussed with seeming indifference to where these differences happen to be found. In fact, however, study of the nervous system has revealed an astonishingly highly organized architecture, with incredible specificity in appearance and in organization. Moreover, differences in organization appear to be closely linked to differences in the functions subserved by different portions of the brain. For example, it is clear that the earlier maturing areas of the cortex are involved in *primary* sensory functions (the perception of discrete sights and sounds) while the later maturing *association* sensory cortexes mediate the meanings of the stimuli and effect connections between sensory modalities (for example, associating seen objects with heard names).

For our purposes, the organizational structure of the nervous system can be considered at two separate levels of detail: a fine-grained or molecular structure, and a grosser or molar structure. While this is also a convenient fiction, it is not a frivolous one; it was in fact recognized in the division of the 1981 Nobel Prize between Roger Sperry, in recent years a student of the molar level, and David Hubel and Torsten Wiesel, students of the molecular structure. And it proves highly relevant to our search for the identity of human intellectual functions.

The Molecular Level. According to Vernon Mountcastle, physiologist at Johns Hopkins University, the human cerebral cortex can be viewed as being organized into columns, or modules. These columns, which are vertical to the surface of the cortex, are approximately 3 millimeters long and between .5 and 1 millimeter across. They are increasingly recognized as forming separate anatomical entities that give rise to different quasi-independent functions. In fact, perception and memory may be distributed through the nervous system in the "person" of these special-purpose "cognitive demons."

These columns were first established in the visual cortex. As Hubel and Wiesel put it:

> given what has been learned about the primary visual cortex, it is clear that one can consider an elementary piece of cortex to be a block about a millimeter square and two millimeters deep. To know the organization of this chunk of tissue is to know the organization for all of the [visual cortex]; the whole must be mainly an integrated version of this elementary unit.

In light of more recent findings, it seems probable that other sensory areas also consist of such columns; and it has even been proposed that the frontal lobe—the area deemed responsible for more abstract and less topographically mapped knowledge—has a columnar organization of this sort.

To what sorts of things do these columns—or their constituent cells—respond? In the visual system, they respond to orientation—horizontal, vertical, oblique—and to ocular dominance—different degrees of eye preference. Less thoroughly understood cortical cells in the visual system may also respond to color, direction of movement, and depth. In the somatosensory system, the columns respond to the side of the field that has been stimulated and to the location of receptors in the skin layers. In the frontal lobe, the columns respond to spatial and temporal information concerning objects that have been present in the organism's field. Taken together, sensory and motor areas appear to contain two-dimensional maps of the world they represent. As information on vision or touch or sound is relayed from one cortical area to the next, the map becomes progressively more blurred and the information carried becomes more abstract.

The columns may turn out to be the fundamental unit of organization throughout evolution. Columns have similar size and shape not only within but also across species. Thus, different species of monkeys may have cortexes of different sizes and different numbers of columns, but the actual dimensions of their columns are the same. Patricia Goldman and Martha Constantine-Paton have speculated that when the number of axons directed in a certain way exceeds a critical number, columns will form as a time-tested and efficient way of filling in the space. Indeed, if one plants an extra eye into a frog during gestation, a column will promptly be set up.

But is the column or module the only way to think of the nervous system? Vernon Mountcastle, whose work led to the discovery of the columnar organization of the nervous system, himself distinguishes between mini-columns (which may have as few as 100 cells and, thereby, constitute the irreducibly small processing unit of the neocortex) and the macrocolumn, each packing several hundred mini-columns inside. Proceeding to a grosser level of organization, Francis Crick suggests the existence of larger distinct areas. The owl monkey, for example, has at least eight cortical areas that are primarily visual: all are perceptually distinct with a fairly well-defined boundary. In his opinion, there are perhaps 50 to 100 discrete areas in the human cortex. As he puts it somewhat wistfully, "if each area could be clearly stained *postmortem*, so that we could see exactly how many there are, how big each one is, and exactly how it is connected to other areas, we would have made a big step forward." It seems clear at this point that one may divide the nervous system into units of widely different sizes. What is important for our inquiry is that, through the appearance and location of different neural units, nature provides important clues about the identity of its valued processes and functions.

The Molar Level. In speculating about larger areas of the cerebral cortex, we move to what has been called a molar level of brain analysis—a level dealing with regions that can be readily inspected by the naked eye. While molecular studies rely heavily on recordings from single cells, visible only under high powers of magnification, the chief source of information about molarity of mind comes from clinical work with brain-damaged patients.

As a result of stroke, trauma, or other accidents, individuals may suffer damage to extensive but still limited regions of the brain. The frontal lobe of the brain may be destroyed, wholly or partially (unilaterally); there may be a lesion in the temporal lobe or at the temporoparietal juncture. The results of this injury can be seen through radiological measures (brain or CAT scans) and can, of course, be examined with great precision in a postmortem. Here is where the scientific payoff inheres. It becomes possible to correlate the loss of sizeable portions of brain tissue—sometimes ones