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Introduction: Evolutionary Psychology and Conceptual Integration

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The Adapted Mind is an edited volume of original, commissioned papers centered on the complex, evolved psychological mechanisms that generate human behavior and culture. It has two goals: The first is to introduce the newly crystallizing field of evolutionary psychology to a wider scientific audience. Evolutionary psychology is simply psychology that is informed by the additional knowledge that evolutionary biology has to offer, in the expectation that understanding the process that designed the human mind will advance the discovery of its architecture. It unites modern evolutionary biology with the cognitive revolution in a way that has the potential to draw together all of the disparate branches of psychology into a single organized system of knowledge. The chapters that follow, for example, span topics from perception, language, and reasoning to sex, pregnancy sickness, and play. The second goal of this volume is to clarify how this new field, by focusing on the evolved information-processing mechanisms that comprise the human mind, supplies the necessary connection between evolutionary biology and the complex, irreducible social and cultural phenomena studied by anthropologists, sociologists, economists, and historians.

Culture is not causeless and disembodied. It is generated in rich and intricate ways by *information-processing mechanisms situated in human minds.* These mechanisms are, in turn, the elaborately sculpted product of the evolutionary process. Therefore, to understand the relationship between biology and culture one must first understand the architecture of our evolved psychology (Barkow, 1973, 1980a, 1989a; Tooby & Cosmides, 1989). Past attempts to leapfrog the psychological—to apply evolutionary biology directly to human social life—have for this reason not always been successful. Evolutionary psychology constitutes the missing causal link needed to reconcile these often warring perspectives (Cosmides & Tooby, 1987).

With evolutionary psychology in place, cross-connecting biology to the social sciences, it is now possible to provide conceptually integrated analyses of specific questions: analyses that move step by step, integrating evolutionary biology with psychology, and psychology with social and cultural phenomena (Barkow, 1989a; Tooby & Cosmides, 1989). Each chapter in this volume is a case study of the difficult task of integrating across these disciplinary boundaries. Although it has been said that the first expressions of new and better approaches often look worse than the latest and most elaborated expressions of older and more deficient ones, we think these chapters are illuminating contributions to the human sciences that stand up well against prevailing approaches. Nevertheless, readers should bear in mind that none of these chapters are meant to be the last word "from biology" or "from psychology"; they are not intended to definitively settle issues. They are better thought of as "first words," intended to open new lines of investigation and to illustrate the potential inherent in this new outlook.

CONCEPTUAL INTEGRATION IN THE BEHAVIORAL AND SOCIAL SCIENCES

Conceptual integration—also known as *vertical integration*[1]—refers to the principle that the various disciplines within the behavioral and social sciences should make themselves mutually consistent, and consistent with what is known in the natural sciences as well (Barkow, 1980b, 1982, 1989a; Tooby & Cosmides, this volume). The natural sciences are already mutually consistent: the laws of chemistry are compatible with the laws of physics, even though they are not reducible to them. Similarly, the theory of natural selection cannot, even in principle, be expressed solely in terms of the laws of physics and chemistry, yet it is compatible with those laws. A conceptually integrated theory is one framed so that it is compatible with data and theory from other relevant fields. Chemists do not propose theories that violate the elementary physics principle of the conservation of energy: Instead, they use the principle to make sound inferences about chemical processes. A compatibility principle is so taken for granted in the natural sciences that it is rarely articulated, although generally applied; the natural sciences are understood to be continuous.

Such is not the case in the behavioral and social sciences. Evolutionary biology, psychology, psychiatry, anthropology, sociology, history, and economics largely live in inglorious isolation from one another: Unlike the natural sciences, training in one of these fields does not regularly entail a shared understanding of the fundamentals of the others. In these fields, paying attention to conceptual integration and multidisciplinary compatibility, while not entirely unknown, is unusual (Campbell, 1975; Hinde, 1987; Symons, 1979). As a result, one finds evolutionary biologists positing cognitive processes that could not possibly solve the adaptive problem under consideration, psychologists proposing psychological mechanisms that could never have evolved, and anthropologists making implicit assumptions about the human mind that are known to be false. The behavioral and social sciences borrowed the idea of hypothesis testing and quantitative methodology from the natural sciences, but unfortunately not the idea of conceptual integration (Barkow, 1989a; Tooby & Cosmides, this volume).

Yet to propose a psychological concept that is incompatible with evolutionary biology is as problematic as proposing a chemical reaction that violates the laws of physics. A social science theory that is incompatible with known psychology is as dubious as a neurophysiological theory that requires an impossible biochemistry. Nevertheless, theories in the behavioral and social sciences are rarely evaluated on the grounds of conceptual integration and multidisciplinary, multilevel compatibility.

With *The Adapted Mind,* we hope to provide a preliminary sketch of what a conceptually integrated approach to the behavioral and social sciences might look like. Contributors were asked to link evolutionary biology to psychology and psychology to culture—a process that naturally entails consistency across fields.

The central premise of *The Adapted Mind* is that there is a universal human nature, but that this universality exists primarily at the level of evolved psychological mechanisms, not of expressed cultural behaviors. On this view, cultural variability is not a challenge to claims of universality, but rather data that can give one insight into the structure of the psychological mechanisms that helped generate it. A second premise is that these evolved psychological mechanisms are adaptations, constructed by natural selection over evolutionary time. A third assumption made by most of the contributors is that the evolved structure of the human mind is adapted to the way of life of Pleistocene hunter-gatherers, and not necessarily to our modern circumstances.

What we think of as all of human history—from, say, the rise of the Shang, Minoan, Egyptian, Indian, and Sumerian civilizations—and everything we take for granted as normal parts of life—agriculture, pastoralism, governments, police, sanitation, medical care, education, armies, transportation, and so on—are all the novel products of the last few thousand years. In contrast to this, our ancestors spent the last two million years as Pleistocene hunter-gatherers, and, of course, several hundred million years before that as one kind of forager or another. These relative spans are important because they establish which set of environments and conditions defined the adaptive problems the mind was shaped to cope with: Pleistocene conditions, rather than modern conditions. This conclusion stems from the fact that the evolution of complex design is a slow process when contrasted with historical time. Complex, functionally integrated designs like the vertebrate eye are built up slowly, change by change, subject to the constraint that each new design feature must solve a problem that affects reproduction better than the previous design. The few thousand years since the scattered appearance of agriculture is only a small stretch in evolutionary terms, less than 1% of the two million years our ancestors spent as Pleistocene hunter-gatherers. For this reason, it is unlikely that new complex designs—ones requiring the coordinated assembly of many novel, functionally integrated features—could evolve in so few generations (Tooby & Cosmides, 1990a, 1990b). Therefore, it is improbable that our species evolved complex adaptations even to agriculture, let alone to postindustrial society. Moreover, the available evidence strongly supports this view of a single, universal panhuman design, stemming from our long-enduring existence as hunter-gatherers. If selection had constructed complex new adaptations rapidly over historical time, then populations that have been agricultural for several thousand years would differ sharply in their evolved architecture from populations that until recently practiced hunting and gathering. They do not (Barkow, 1980a, 1989a, 1990).

Accordingly, the most reasonable default assumption is that the interesting, complex functional design features of the human mind evolved in response to the demands of a hunting and gathering way of life. Specifically, this means that in relating the design of mechanisms of the mind to the task demands posed by the world, "the world" means the Pleistocene world of hunter-gatherers. That is, in considering issues of functionality, behavioral scientists need to be familiar with how foraging people lived. We cannot rely on intuitions honed by our everyday experiences in the modern world. Finally, it is important to recognize that behavior generated by mechanisms that are adaptations to an ancient way of life will not necessarily be adaptive in the modern world. Thus, our concern in this volume is with adaptations—mechanisms that evolved by natural selection—and not with modern day adaptiveness (Symons, this volume; see also Barkow, 1989a, 1989b).

Aside from the two opening, orienting chapters and the concluding one, each chapter of *The Adapted Mind* focuses on an adaptive problem that our hunter-gatherer ancestors would have faced: a problem that affected reproduction, however distally, such as finding mates, parenting, choosing an appropriate habitat, cooperating, communicating, foraging, or recovering information through vision. We asked each contributor to consider three questions: (1) What selection pressures are most relevant to understanding the adaptive problem under consideration?; (2) What psychological mechanisms have evolved to solve that adaptive problem?; and (3) What is the relationship between the structure of these psychological mechanisms and human culture? We chose these three questions because there are interesting causal relationships between selection pressures and psychological mechanisms on the one hand, and between psychological mechanisms and cultural forms on the other.

There is now a rich literature in evolutionary biology and paleoanthropology that allows one to develop useful models of selection pressures, and there have been for many decades in anthropology, sociology and other social sciences rich descriptions of social and cultural phenomena. Using the above three questions, *The Adapted Mind* is intended to supply the missing middle: the psychological mechanisms that come between theories of selection pressures on the one hand and fully realized sociocultural behavior on the other. By concentrating on evolved mechanisms, this collection represents a departure from both traditional anthropology and various evolutionarily inspired theories of culture and behavior. Although both of these fields recognize that culture and cultural change depend critically upon the transmission and generation of information, they have frequently ignored what should be the causal core of their field: the study of the evolved information-processing mechanisms that allow humans to absorb, generate, modify, and transmit culture—the psychological mechanisms that take cultural information as input and generate behavior as output (Barkow, 1978, 1989a; Tooby & Cosmides, 1989). Our goal in this collection is to focus on these mechanisms in order to see where a more precise understanding of their structure will lead.

Because an evolutionary perspective suggests that there will be a close functional mesh between adaptive problems and the design features of the mechanisms that evolved to solve them, each chapter of *The Adapted Mind* focuses on an adaptive problem, and each discusses what kind of psychological mechanisms one might expect natural selection to have produced to solve that problem. Evidence from the literatures of psychology, anthropology, and evolutionary biology was brought to bear on these hypotheses whenever possible. Many of the authors also addressed a few of the implications that the psychological mechanisms they studied might have for culture. The relationship between psychology and culture can be complex, and in some cases the psychological mechanisms are not yet sufficiently well-understood to make any meaningful statement. Nevertheless, in the interests of conceptual integration, the contributors to *The Adapted Mind* have tried, insofar as it has been possible, to bring data from cross-cultural studies to bear on their psychological hypotheses, to point out when the psychological mechanisms discussed can be expected to cause variation or uniformity in practices, preferences, or modes of reasoning across cultures, or to discuss what implications the psychological mechanisms concerned might have for various theories of cultural change.

BASIC CONCEPTS IN EVOLUTIONARY PSYCHOLOGY AND BIOLOGY

The organization of *The Adapted Mind* is unusual: Few works in psychology or the social sciences are organized around adaptive problems. The decision to do so was theoretically motivated. The first two chapters, "The Psychological Foundations of Culture," by Tooby and Cosmides, and "On the Use and Misuse of Darwinism in the Study of Human Behavior," by Symons, as well as the last chapter, "Beneath New Culture Is Old Psychology," by Barkow, present the theoretical program that animates this volume (see also Barkow, 1989a, 1990; Brown, 1991; Cosmides & Tooby, 1987; Daly & Wilson, 1988; Sperber, 1985; Symons, 1979; Tooby & Cosmides, 1989, 1990b). But because this volume is aimed at a broad social science audience, each discipline of which is familiar with different concepts and terms, it may prove helpful to begin with a brief orientation to what the contributors to this volume mean when they use terms such as *mind, selection, adaptive problem,* and *evolutionary psychology.*

Evolutionary psychology is psychology informed by the fact that the inherited architecture of the human mind is the product of the evolutionary process. It is a conceptually integrated approach in which theories of selection pressures are used to generate hypotheses about the design features of the human mind, and in which our knowledge of psychological and behavioral phenomena can be organized and augmented by placing them in their functional context. Evolutionary psychologists expect to find a functional mesh between adaptive problems and the structure of the mechanisms that evolved to solve them. Moreover, every psychological theory—even the most doctrinairely "anti-nativist"—carries with it implicit or explicit evolutionary hypotheses. By making these hypotheses explicit, one can evaluate whether psychological theories are consistent with evolutionary biology and paleoanthropology and, if not, investigate which field needs to make changes.

There are various languages within psychology for describing the structure of a psychological mechanism, and many evolutionary psychologists take advantage of the new descriptive precision made possible by cognitive science. Any system that processes information can be described in at least two different, mutually compatible and complementary ways. If asked to describe the behavior of a computer, for example, one could characterize the ways in which its physical components interact—how electrons flow through circuits on chips. Alternatively, one could characterize the programs that the system runs—what kind of information the computer takes as input, what rules or algorithms it uses to transform that information, what kinds of data structures (representations) those rules operate on, what kinds of output it generates. Naturally, programs run by virtue of the physical machine in which they are embodied, but an information-processing description neither reduces to nor can replace a physical description, and vice versa. Consider the text-editing program "Wordstar." Even though it can run on a variety of different hardware architectures, it always has the same functional design—the same key strokes will delete a line, move a block of text, or print out your file. It processes information in the same way no matter what kind of hardware it is running on. Without an information-processing description of Wordstar, you will not know how to use it or what it does, even if you are intimately acquainted with the hardware in which it is embodied. A physical description cannot tell one what the computer was designed to do; an information-processing description cannot tell one the physical processes by virtue of which the programs are run.

In psychology, it has become common to describe a brain as a system that processes information—a computer made out of organic compounds rather than silicon chips. The brain takes sensorily derived information from the environment as input, performs complex transformations on that information, and produces either data structures (representations) or behavior as output. Consequently, it, too, can be described in two mutually compatible and complementary ways. A neuroscience description characterizes the ways in which its physical components interact; a cognitive, or information-processing, description characterizes the "programs" that govern its operation. In cognitive psychology, the term *mind* is used to refer to an information-processing description of the functioning of the brain, and not in any colloquial sense. Behavioral descriptions can be illuminating, but manifest behavior is so variable that descriptions that capture and explain this variability inevitably require an explication of the psychological mechanisms and environmental conditions that generate it (see Symons, this volume).

An account of the evolution of the mind is an account of how and why the information-processing organization of the nervous system came to have the functional properties that it does. Information-processing language—the language of cognitive psychology—is simply a way of getting specific about what, exactly, a psychological mechanism does. In this volume, most psychological mechanisms are described in information-processing terms, either explicity or implicity. Research in some areas of psychology is so new that it is too early to develop hypotheses about the exact nature of the rules and representations involved. Nevertheless, the contributors have focused on the kinds of questions that will allow such hypotheses to be developed, questions such as: What kinds of information are available in the environment for a psychological mechanism designed for habitat selection, or mate selection, or parenting to use? Is there evidence that this information *is* used? If so, how is it evaluated? What kinds of affective reactions does it generate? How do people reason about this information? What information do they find memorable? What kinds of information are easy to learn? What kinds of decision rules guide human behavior? What kinds of cross-cultural patterns will these mechanisms produce? What kinds of information will they cause to be socially transmitted?

One doesn't have to look far to find minds that are profoundly different from our own: The information-processing mechanisms that collectively comprise the human mind differ in many ways from those that comprise the mind of an alligator or a bee or a sparrow or a wolf. The minds of these different species have different *design features:* different perceptual processes, different ways of categorizing the world, different preferences, different rules of inference, different memory systems, different learning mechanisms, and so on. These differences in psychological design cause differences in behavior: Upon perceiving a rattlesnake, a coyote might run from it, but another rattlesnake might try to mate with it.

Darwin provided a naturalistic explanation for the design features of organisms, including the properties of the minds of animals, not excepting humans. He wanted to explain how complex functional design could emerge in species spontaneously, without the intervention of an intelligent artificer, such as a divine creator. Darwin's explanation—natural selection—provides an elegant causal account of the relationship between adaptive problems and the design features of organisms. An *adaptive problem* is a problem whose solution can affect reproduction, however distally. Avoiding predation, choosing nutritious foods, finding a mate, and communicating with others are examples of adaptive problems that our hominid ancestors would have faced.

The logic of his argument seems inescapable. Imagine that a new design feature arises in one or a few members of a species, entirely by chance mutation. It could be anything—a more sensitive retina, a new digestive enzyme, a new learning mechanism. Let's say that this new design feature solves an adaptive problem better than designs that already exist in that species: The more sensitive retina allows one to see predators faster, the new digestive enzyme allows one to extract more nutrients from one's food, the new learning mechanism allows one to find food more efficiently. By so doing, the new design feature causes individuals who have it to produce more offspring, on average, than individuals who have alternative designs. If offspring can inherit the new design feature from their parents, then it will increase in frequency in the population. Individuals who have the new design will tend to have more offspring than those who lack it, those of their offspring who inherit the new design will have more offspring, and so on, until, after enough generations, every member of the species will have the new design feature. Eventually, the more sensitive retina, the better digestive enzyme, the more reliable learning mechanism will become universal in that species, typically found in every member of it.

Darwin called this process *natural selection.* The organism's interaction with the environment—with "nature"—sets up a feedback process whereby nature "selects" one design over another, depending on how well it solves an adaptive problem (a problem that affects reproduction).

Natural selection can generate complex designs that are *functionally organized*—organized so that they can solve an adaptive problem—because the criterion for the selection of each design feature is functional: A design feature will spread only if it solves an adaptive problem better than existing alternatives. Over time, this causal feedback process can create designs that solve adaptive problems well—designs that "fit" the environment in which the species evolved. Random processes, such as mutation and drift, cannot, by themselves, produce complex designs that are functionally organized because the probability that all the right design features will come together simply by chance is vanishingly small. By definition, random processes contain no mechanism for choosing one design over another based on its functionality. Evolution by natural selection is the only presently validated explanation for the accumulation of functional design features across generations.

The emerging field of evolutionary psychology attempts to take advantage of Darwin's crucial insight that there should be a functional mesh between the design features of organisms and the adaptive problems that they had to solve in the enviroment in which they evolved. By understanding the selection pressures that our hominid ancestors faced—by understanding what kind of adaptive problems they had to solve—one should be able to gain some insight into the design of the information-processing mechanisms that evolved to solve these problems. In doing so, one can begin to understand the processes that underlie cultural phenomena as well.

COMPLEMENTARY APPROACHES TO FUNCTIONAL ANALYSIS

The most common approach that evolutionarily oriented behavioral scientists have taken is to start with a known phenotypic phenomenon, such as pregnancy sickness, language, or color vision, and to try to understand what its adaptive function was—why that design was selected for rather than alternative ones. To do this, one must show that it is well designed for solving a specific adaptive problem, and that it is not more parsimoniously explained as a by-product of a design that evolved to solve some other adaptive problem (Williams, 1966; Symons, this volume). This is a difficult enterprise, but a necessary one: Until one understands a mechanism's adaptive function, one does not have a fully satisfying, conceptually integrated account of why it exists and what it does. More critically, asking functional questions and placing the phenomenon in a functional context often prompts important new insights about its organization, opening up new lines of investigation and bringing to light previously unobserved aspects and dimensions of the phenomenon. A number of contributions to *The Adapted Mind* take this approach (e.g., Boulton & Smith, Nesse & Lloyd, Profet, Pinker & Bloom, and Shepard). Going from a known psychological phenomenon to a theory of adaptive function is the most common form of conceptual integration between evolutionary biology and psychology.

With equal validity, however, one can take the analysis in the opposite direction as well (see Figure I.1). One can use theories of adaptive function to help one discover psychological mechanisms that were previously unknown. When one is trying to discover the structure of an information-processing system as complex as the human brain, knowing what its components were "designed" to do is like being given an aerial map of a territory one is about to explore by foot. If one knows what adaptive functions the human mind was designed to accomplish, one can make many educated guesses about what design features it should have, and can then design experiments to test for them. This can allow one to discover new, previously unsuspected, psychological mechanisms.

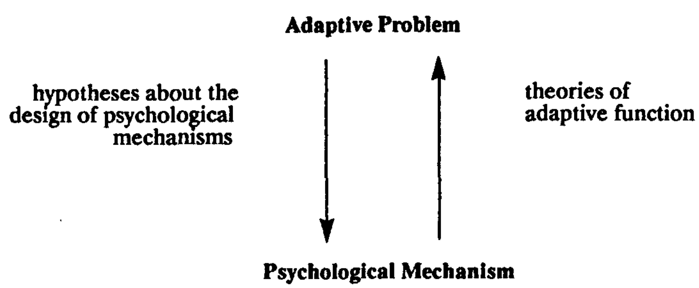

Figure I.1 The consideration of adaptive function can inform research into human behavior and psychological architecture in a variety of ways. The two most direct paths are schematized here. First, knowledge of the adaptive problems and ancestral conditions that human hunter-gatherers faced can lead to new hypotheses about the design of psychological mechanisms that evolved to solve them. Such heuristic analyses can supply crucial guidance in the design of experiments to discover previously unknown psychological mechanisms—investigations that researchers who neglect functional analysis would not have thought to conduct. Secondly, researchers can start with a known psychological phenomenon, and begin to investigate its adaptive function, if any, by placing it in the context of hunter-gatherer life and known selection pressures. The discovery of the functional significance of a psychological phenomenon is not only worthwhile in its own right, but clarifies the organization of the phenomenon, and prompts the discovery of new associated phenomena.

Empirically minded researchers, distrustful of "theory" (by which they often mean facts or principles drawn from unfamiliar fields), frequently ask why they should bother thinking about evolutionary biology: Why not just investigate the mind and behavior, and simply report what is found? The answer is that understanding function makes an important and sometimes pivotal contribution to understanding design in systems that are otherwise bewildering in their complexity. This point is illustrated by a story from the engineering community about the utility of knowing something's function. Reportedly, at a conference, an engineering professor carried a relatively simple circuit around to the various participants, asking them each to guess what its function was. Despite many guesses, none of the assembled engineers was able to figure it out. Finally, on the last day of the conference, the professor went up to the podium and asked the audience members to sketch the design of a circuit that would be able to perform a function that he then named. Everyone was able to do this rapidly, and when they were finished they were surprised to see that they had just drawn a picture of the same circuit that he had been showing them, the circuit whose function they had been unable to guess.[2] Behavioral scientists have been nearly defeated by the complexity of the behavior they confront. Guidance as to function vastly simplifies the problem of organizing the data in a way that illuminates the structure of the mind.

Our hominid ancestors had to be able to solve a large number of complex adaptive problems, and do so with special efficiency. By combining data from paleontology and hunter-gatherer studies with principles drawn from evolutionary biology, one can develop a task analysis that defines the nature of the adaptive information-processing problem to be solved. David Marr (1982) called this kind of task analysis a *computational theory.* Once one understands the nature of the problem, one can then generate very specific, empirically testable hypotheses about the structure of the information-processing mechanisms that evolved to solve it. A number of contributors to *The Adapted Mind* adopted this research strategy (e.g., Buss, Cosmides & Tooby, Mann, Silverman & Eals). One virtue of this approach is that it is immune to the usual (but often vacuous) accusation of post hoc storytelling: The researcher has predicted in advance the properties of the mechanism.

Using an evolutionarily derived task analysis to generate hypotheses about the structure of our cognitive processes can lead one to look for mechanisms that would otherwise have been overlooked. Silverman and Eals's chapter on spatial cognition is a good example. Research on spatial cognition has been proceeding for 100 years without the benefit of an evolutionary perspective, and the only kinds of mechanisms discovered were ones that produced a male performance advantage. But by asking what kind of spatial cognition a Pleistocene woman would have needed to be good at solving the adaptive problem of foraging for plant foods, Silverman and Eals were able to discover a new class of mechanisms involved in spatial cognition, which produce a 60% female advantage.

Psychologists should be interested in evolutionary biology for the same reason that hikers should be interested in an aerial map of an unfamiliar territory that they plan to explore on foot. If they look at the map, they are much less likely to lose their way.

THE HARVEST OF CONCEPTUAL INTEGRATION

Conceptual integration has been such a powerful force in the natural sciences not only because it allows scientists to winnow out improbable hypotheses or build aesthetically pleasing bridges between disciplines, but because it has been crucial to the discovery of new knowledge. For example, the atomic theory allowed chemists to see thermodynamics in a new way: The atomic theory was connected to Newtonian mechanics through the kinetic theory of heat, and thermodynamics was recast as statistical mechanics. When quantum theory was subsequently developed in physics, statistical mechanics was modified in such a way that it could explain not only the thermal and mechanical properties of matter, but its magnetic and electrical properties as well (Holton, 1973). The emergence of Mendelian genetics at the turn of the century solved a major puzzle in Darwinian theory. By showing that pre-Mendelian theories of blending inheritance were false—i.e., that tall and short plants need not produce medium offspring, that red and white flowers need not produce pink flowers, and so on—Mendelian genetics showed that natural selection could, in fact, create new species, a proposition that theories of blending inheritance had called into question. Subsequently, the combination of Mendelian genetics, Darwinian theory, and newly developed approaches to statistics led to the Modern Synthesis, which in turn made possible a family of new sciences, from population genetics to behavioral ecology.

Conceptual integration generates this powerful growth in knowledge because it allows investigators to use knowledge developed in other disciplines to solve problems in their own. The causal links between fields create anchor points that allow one to bridge theoretical or methodological gaps that one's own field may not be able to span. This can happen in the behavioral and social sciences, just as it has happened in the natural sciences. Evidence about cultural variation can help cognitive scientists decide between competing models of universal cognitive processes; evidence about the structure of memory and attention can help cultural anthropologists understand why some myths and ideas spread quickly and easily while others do not (e.g., Mandler et al., 1980; Sperber, 1985, 1990); evidence from evolutionary biology can help social psychologists generate new hypotheses about the design features of the information-processing mechanisms that govern social behavior; evidence about cognitive adaptations can tell evolutionary biologists something about the selection pressures that were present during hominid evolution; evidence from paleoanthropology and hunter-gatherer studies can tell developmental psychologists what kind of environment our developmental mechanisms were designed to operate in; and so on.

At present, crossing such boundaries is often met with xenophobia, packaged in the form of such familiar accusations as "intellectual imperialism" or "reductionism." But by calling for conceptual integration in the behavioral and social sciences we are neither calling for reductionism nor for the conquest and assimilation of one field by another. Theories of selection pressures are not theories of psychology; they are theories about some of the causal forces that produced our psychology. And theories of psychology are not theories of culture; they are theories about some of the causal mechanisms that shape cultural forms (Barkow, 1973, 1978, 1989a; Daly & Wilson, 1988; Sperber, 1985, 1990; Tooby & Cosmides, 1989, this volume). In fact, not only do the principles of one field not reduce to those of another, but by tracing the relationships between fields, additional principles often appear.

Instead, conceptual integration simply involves learning to accept with grace the irreplaceable intellectual gifts offered by other fields. To do this, one must accept the tenet of mutual consistency among disciplines, with its allied recognition that there are causal links between them. Compatibility is a misleadingly modest requirement, however, for it is an absolute one. Consequently, accepting these gifts is not always easy, because other fields may indeed bring the unwelcome news that favored theories have problems that require reformulation. Inattention to the compatibility requirement has led to many conceptual wrong turns in the social sciences (Barkow, 1989a; Tooby & Cosmides, this volume) as well as in evolutionary biology (Symons, this volume; Tooby & Cosmides 1990b). But fortunately errors can be avoided in the future by scrutinizing hypotheses in each field in the light of what is known in other fields. Investigators planning to apply such an approach will need to develop simultaneous expertise in at least two "adjacent" fields. Toward this end we hope that training in the behavioral and social sciences will move away from its present fragmented and insular form and that students will be actively encouraged to gain a basic familiarity with relevant findings in allied disciplines.

In the final analysis, it is not unaided empiricism that has made the natural sciences so powerful, but empiricism wedded to the power of inference. Every field has holes and gaps. But when there are causal links that join fields, the holes that exist in one discipline can sometimes be filled by knowledge developed in another. What the natural sciences have discovered is that this is a process with positive feedback: The more that is known—the more that can be simultaneously brought to bear on a question—the more that can be deduced, explained, and even observed. If we, as behavioral and social scientists, change our customs and accept what mutual enrichment we can offer one another, we can be illuminated by the same engine of discovery that has made the natural sciences such a signal human achievement.

NOTES

1. The idea that two statements cannot contradict each other and both be true was old when Aristotle formalized it, and it is only a small step from that to the commonplace idea that claims from different scientific disciplines should not contradict each other either, without at least one of them being suspected of being in error. Such a notion would seem too obvious to discuss were it not for the bold claims of autonomy made for the social sciences, accompanied by the institutionalized neglect of neighboring disciplines (Barkow, 1989c). It is, perhaps, one of the astonishing features of intellectual life in our century that cross-disciplinary consistency should be treated as a radical claim in need of defense, rather than as a routine tool of inference (Tooby & Cosmides, this volume). In any case, the central idea is simply one of consistency or compatibility across sciences, and conceptual integration and vertical integration are simply different names for this principle.

The adjective *vertical* in *vertical integration* (Barkow, 1980b, 1982, 1989a) emphasizes, alongside the notion of mutual compatibility, the notion that certain disciplines exist in a structured relationship with each other, such as physics to chemistry, and chemistry to biology. Each field "lower" in such a structure deals with principles that govern more inclusive sets of phenomena. For example, the laws of physics apply to chemical phenomena, and the principles of physics and chemistry apply to biological phenomena, but not the reverse. By the same token, however, each field "higher" up in the structure requires additional principles special to its more restricted domain (e.g., living things, humans) that are not easily reduced to the principles found in the other fields (e.g., natural selection is not derivable from chemistry).

We will generally use the term "conceptual integration" to avoid the connotation that vertical relationships between disciplines imply some epistemological or status hierarchy among sciences. For example, Lord Kelvin's criticism of Darwinism was based on Kelvin's erroneous calculation of the age of the earth. This case demonstrates that when physics and biology conflict, it is certainly possible that physics is in error. Moreover, the array of modern disciplines (from geochemistry to astrophysics to paleodemography to neuropharmacology) makes heterarchical relationships often seem more natural than any vertical ordering. Sciences should learn from and strive for consistency with every other field, from those existing in a clearly vertical relationship, such as chemistry is to physics, to those standing in more complex relationships, such as paleontology to psychology.

2. Our thanks to Jim Stellar for passing on to us this parable about the usefulness of functional approaches.

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