CHAPTER 1

THE EVOLUTION REVOLUTION

"We can no more keep evolution out of psychology than we can keep psychology out of human evolution."

— Henry Plotkin (1998)

WHY EVOLUTION?

A revolution is occurring in psychology. It stems from the realization that psychology can be studied as a biological science, a science that takes a living thing as its subject matter. Because biology is the science of living things, psychology is by definition a part of the broad scope of biology. Even if university psychology departments are separate from biology departments, the discipline of psychology owes much of its intellectual base to its broader relationship with biological sciences, for biology provides a theoretical orientation that can unite all of psychology under a single framework.

If psychology recognizes its relationship to biology, it also recognizes the basic theory that underlies all of biology: Charles Darwin's theory of **evolution by natural selection**. In his book *On the Origin of Species* (1859), Darwin observed that most organisms produce far more offspring than will ever mature and reproduce. Most are lost to disease, predators, or competition with other members of their species. If those that survive and reproduce have a different genetic inheritance from those who do not, the genes of those survivors will become more frequent in the next generation. The insight that drives evolutionary psychology is that the adapted characteristics of the successful reproducers include not only features of the body, such as strong hearts and resistance to disease, but also behavioral capabilities, attitudes, and motivations.

The theory requires three conditions. First, there must be some *variation* in the members of a species, a variation that is at least partly due to differences in their **genes**. Second, the survival of members of the species must depend on the differences in their genetic inheritance, a *selection* of some individuals over others. Third, there must be a *retention* of the selected traits by the descendants of the selected individuals. Because almost all natural populations meet all three conditions, evolution by natural selection is nearly universal among living species. Humans are no exception.

Biologists recognize evolution as the basis of biological thought, with its accounts of what organisms are and how they come to be the way they are. Evolution is an epic tale, the constant selection of the most successful individuals for more than 3 billion years. The great stretch of evolutionary development means that it takes more than physics and chemistry to explain life—the history of life is important too, as random accidents of genetic mutation or lucky combinations of genes change the direction of life itself.

We are the products of millions of genetic accidents, some lucky, some less fortunate, and of environmental changes as sweeping as the changes in our genes. Any organism is a bundle of **adaptations**, specific bits of physical machinery originating in the genes, developing in a particular environment, and increasing the biological success of the organism. The adaptations of the most interest here are not the physical structures of the legs, the heart, or the eyes, but the brain structures that endow us with particular capabilities and motivations.

Psychologists who study perception, memory, or brain processes take for granted that evolutionary theory is indispensable to their work. No scientist would propose a theory of human vision, for instance, that was not consistent with what we know about vision in monkeys. After all, the visual pigments of the eye, the chemicals that start the whole process, are nearly identical not only in humans and monkeys, but also in animals as distant from us as fruit flies. So are the nerve cells that carry the signals from the eye. They evolved only once, and all animal life shares ancient evolutionary inventions like these. Because of our common origins, we can understand some aspects of human vision by examining the visual machinery of fruit flies.

This interpretation of psychology as a part of biology can be applied not just to physiological studies but to all of psychology: to social psychology as much as perception, and even to clinical practice. In each of these areas, the contribution of evolutionary theory will be different, depending on the roles of culture, history, social interactions, and biological structure in their makeup.

Evolutionary Psychology

The gathering revolution in psychology is based on the insight that evolution is critical for understanding not only the physiology of our bodies but also our perceptions, experiences, and behaviors. For the human is an animal like any other, a very successful one, but as much dependent on its biological inheritance as any monkey or fly. We come into the world with an enormous heritage of biological structure that affects everything about us, including how we pick up information from our environment and from our society.

Human behavior and experience cannot be understood without knowing what this biological equipment is and what possibilities and limitations it offers. For example, the human eye responds best to the range of wavelengths that is present in natural sunlight. Because most of the information that we can pick up from the visual environment is contained in this range of wavelengths, natural selection has given us biological mechanisms of vision that work where they are most effective. In a similar way, we are adapted to solve the cognitive and social challenges that our ancestors faced. To investigate these challenges, we must study both the environment and the adaptations, though—the genetics of color vision won't be interpretable without knowledge of the spectrum of sunlight.

Evolutionary psychology, then, is "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" (Cosmides & Barkow, 1992). The new psychology is inclusive, sweeping both traditional psychological inquiry and insights from biology and other disciplines into its web. It applies the principles of biological evolution to the great questions of psychology: What are the bases of experience, behavior, mind, and memory, of development and social interaction? Where do they come from, and what are they for? The study of evolutionary psychology links all of these questions together by grounding them in a consistent theoretical orientation.

This does not mean that a psychology recognizing the key role of evolution in organizing human behaviors and attitudes should ignore culture, or assign it only secondary importance. The interaction of genes and culture is older than humanity itself. All the work of psychologists on the effects of culture on behavior is made no less valid by an evolutionary perspective, because culture profoundly affects every aspect of human life.

Psychology from the standpoint of evolutionary theory has reaffirmed, in fact, that culture affects human adaptations at every level, from social and linguistic adaptations all the way down to the structure of our teeth. (Teeth could evolve to become smaller only after cultural inventions such as fire and cooking changed our diet.) If this book emphasizes biological contributions to the human condition, it is partly to redress a historical imbalance in thinking about the sources of human behavior.

● SOCIAL SCIENCE VIEWS OF HUMANS

We humans sometimes like to think of ourselves as above nature or apart from it, as if our technology and culture have freed us from the biological limitations that chain other animals to particular ways of life. A squirrel, for instance, is trapped forever in woodlands, storing and eating nuts, whereas humans can live in woodlands, plains, jungles, deserts, arctic tundra, almost anywhere, can eat anything and can change lifestyles without genetic modification. Social science often embraces this conceit, with a conception of the human being traditionally influenced by philosopher John Locke's view of the mind as a **tabula rasa**, a blank slate on which the content of one's culture is written. According to this view, we have some structure, to be sure, but it is only a physical framework that we share with animals. The content and even the organization of the mind are free to vary as its culture demands.

Evidence for the centrality of this interpretation of the social sciences comes directly from the founders of the modern social sciences. Working about a century ago, they were quite explicit about the dominant role that culture and environment would play in their new disciplines. Emile Durkheim, perhaps the founder of modern sociology, wrote, "Individual natures are merely the indeterminate material that the social factor molds and transforms" (Durkheim, 1895/1962, p. 106). With such a beginning, it is no surprise that even today sociology pays little heed to the biological structure of the people who make up societies.

Psychology has had a similar history. It developed from several sources, one of them as an outgrowth of a European philosophy that was linked only indirectly to the natural sciences. In the United States, this philosophical tradition led many early psychologists to reject any significant influence of biological structure on the fates of individual humans. John Watson founded the **behaviorist** school, which dominated psychology in the United States from the 1920s until the 1960s and still influences psychological thought. In a famous boast he wrote:

> Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, artist, merchant-chief, and yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors. (Watson, 1925, p. 82)

At least we can give him credit for not being racist. Watson went on to insist that psychology could be built from presenting stimuli and measuring behavioral responses, correlating the two without regard to the internal structure of the organism. As it turned out, this stimulus-response approach proved to be too simple to account for even the behavior of laboratory rats, let alone humans. In the words of psychologist Don Symons (quoted in Allman, 1994), "There is no such thing as a 'general problem solver' because there is no such thing as a general problem."

In a highly structured learning situation, for example, behaviorists predicted that a rat would respond only to the stimuli that will result in a reward. The rat, however, has other ideas. It explores its training cage, sniffs everything, marks its tiny territory, and generally spends a lot of time engaged in behaviors that the behaviorist cannot explain. Although in its time behaviorism represented a great step forward in demanding scientific and methodological rigor, it is no longer seen as a viable psychology.

The Standard Social Science Model

These and similar founding ideas have led to an attitude of the social sciences to the role of biological structure, termed the **Standard Social Science Model (SSSM)** (Tooby & Cosmides, 1992). In this model, the human tabula rasa is a general-purpose brain, into which not only the technologies and conventions of a culture but also the most basic hopes and fears, needs and attitudes, are added from the outside. The SSSM assumes that the mind is highly malleable, its structure depending on what it experiences during development. Genes and instincts are there, but their influence remains in the background, offering a wide range of possibilities. Just as a general-purpose computer can become a typewriter, a calculator, a mailbox, or a hundred other tools, depending on a program added from the outside, the SSSM's human can become doctor, lawyer, or thief, depending only on its environment.

Psychology began long before Watson as an effort to analyze the mind into its constituent parts, much as chemistry had already analyzed matter into its elements. The new science of the mind did not link itself intellectually to chemistry or to the other natural sciences, however. All of the natural sciences are tied together—facts of biology are explained in terms of chemistry, chemical processes are understood in terms of physics, and so on. Together they form a broad and consistent body of knowledge. E. O. Wilson (1998) calls this process **consilience**. The relationships among the natural sciences are not reductionistic, however—each adds something unique that cannot emerge from the previous level (Hass et al., 2000). Biology, for instance, includes a body of facts and theories that cannot be derived from chemistry, and not all chemical facts and theories can be derived from physics, but theories in each discipline must be consistent with established principles in all the others.

The social sciences in contrast talk to one another much less; each works independently of the others. Psychology does not use anthropology to explain the nature of humanity, and sociologists pay little heed to explanations from psychologists in understanding social behavior. Anthropologists study differences among human groups, whereas sociologists are more concerned with modern Western society. Economists often assume that people are rational and will optimize their economic behavior, without looking at a wealth of disconfirming evidence from psychology. Sigmund, Fehr, and Nowak (2002) caricature economists as studying a mythical Homo Economicus, making rational choices in complete isolation.

According to Hass et al. (2000), the various social sciences seem to be parallel rather than hierarchical, each explaining human behavior and experience in its own way. What they have in common is the SSSM, the idea that the critical variables for understanding human behavior, experience, and social structure are primarily environmental and cultural rather than biological. Human nature in this view is reduced to not much more than a capacity for culture. Because social scientists are trained to seek environmental explanations for all of their observations, they often tend to avoid alternative explanations. Consilience is not an issue. Of course every discipline has its scholars who do pay attention to other disciplines and to their biological base, and the SSSM is one end of a continuum from environmental determinism to biological determinism, but its influence remains significant.

Though there is value in the SSSM insight that environment and development are critically important in understanding the human situation, this book will examine whether the SSSM conception of the mind as unstructured and culture as apart from nature is consistent with what we know about how human beings are put together.

The SSSM's mind is like a trellis upon which a culture grows—and it can grow in any direction that its history takes it. The biological trellis, though, channels that vine in some directions and prevents development in others. Research has begun to reveal more structure in that trellis than anyone had dared imagine. The social sciences are at last beginning to become broader and more interdisciplinary, linked more closely with the natural sciences and with one another. This book is a part of the movement in that direction.

Several forces have led to the current efforts to establish a more broadly based psychology, with roots in both biological and social science. One influence has been the limitations that have emerged in the SSSM, with the social sciences making little progress in understanding the human condition. According to some psychologists,

> The social sciences are still adrift, with an enormous mass of half-digested observations, a not inconsiderable body of empirical generalizations, and a contradictory stew of ungrounded middle-level theories expressed in a babel of incommensurate technical lexicons. (Tooby and Cosmides, 1992, p. 23)

By this assessment, it is surprising that we know anything at all about people and their societies. The situation is beginning to improve, with efforts to integrate social sciences and evolutionary theory (Gandolfi, Gandolfi, & Barash, 2002).

Another impetus for the evolutionary approach is the enormous power of new biological tools that we can apply to psychological problems, tools that include our new ability to study, sequence, and define the genes themselves, and a theoretical reorientation that allows us to ask new questions and progress in unexpected directions. A century and a half of progress in biology, understanding what Darwin's (1859) evolution by natural selection means and how it works, can now be applied to the problems of psychology. Let's get started.

● NATURE VERSUS NURTURE?

Questions about biological and environmental influences on a human trait are often phrased in the SSSM as "nature versus nurture," a framework that pits one cause in competition against the other. It is as though both heredity and environment can fill the bucket of the human mind, and the question becomes how much water enters the bucket from each source. As a result, interactions between the two causes are viewed as competitions among equals, as though these two giants are struggling with one another for control of the human mind.

But the competitive framework misinterprets the way in which human traits come to be. It is not a matter of nature and nurture competing for influence. Rather, every trait begins with genes that direct the construction of every part of the body and the brain. The trait of running speed of an individual human is a good example for understanding this process in the context of psychology, because it is defined by a behavior rather than by a physical characteristic. For running speed, genes largely set the length of the legs, the rate of metabolism, and other body properties that will influence speed.

Without an organism, though, the genes are just bits of deoxyribonucleic acid, **DNA**, microscopic wisps of organic molecules that seem unrelated to running speed or any other trait. They acquire their power over traits only in the right environment, in an organism that develops according to the genes' instructions. The environment also allows the genes to do their work either more effectively or less effectively, and in the end running speed is tested in an environment. Good nutrition, for instance, allows the genes to develop strong muscles in the good runner. Without that nutrition, the good genes won't matter, because the raw materials they need to do their work are not at hand.

So the organization of genes and environment is not parallel but sequential: every trait begins with genes. They work through an environment to create an organism with certain traits (Figure 1.1). All the genes together constitute a **genotype**, the set of genes that an organism starts with, and the genes and environment together in turn direct the development of a **phenotype**, the actual properties of the physical organism. Eventually, the success of a phenotype influences the structure of the genotype, by survival of the individuals with the most successful phenotypes. These individuals then contribute their genotypes to the next generation.

Seen in this way, it doesn't make sense to ask whether nature or nurture has the stronger influence: all traits are determined by genes working through an environment to create an organism with traits.

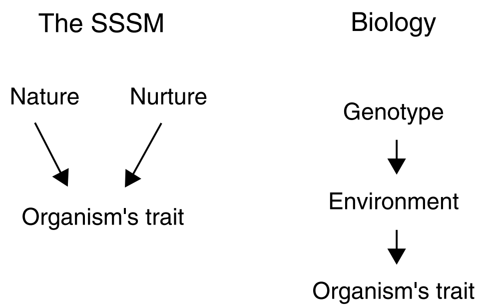

Figure 1.1 Alternative conceptions of environmental and genetic contributions to an organism's traits.

Heritability

There is one restricted instance in which one can distinguish what heredity and environment contribute, and this is in the distribution of a trait in a population. The range of running speeds of all the students in a classroom, for instance, will be determined both by their genetic diversity and by the diversity of their environments, including both their current condition and their circumstances during development. If all the people in the class had the same genes, for example (admittedly an unlikely situation), there would be less variability of running speed, and all of it would be contributed by the environment. If instead all the students had identical environments (even more unlikely), there would again be less variability of running speed, but all of it would come from genetic differences.

These extreme examples show that the proportion of the variability contributed to a group by genes and by environment is not fixed, but is affected by the variability of the genes and of the environments themselves. In the real world, each influence, heredity, and environment contributes something to the diversity of capabilities in the group. **Heritability**, the proportion of a population's variance on a trait that can be accounted for by differences in genes among its members, depends on the variability of the group as well as the genetic origins of the trait.

The nature of that influence from genetics, which changes only between generations, will be fundamentally different from the effects of the environment, which changes individuals within a generation but cannot influence succeeding generations. And in the end we will have to stage a race to determine how fast each member of our population can run, introducing another source of error into our estimate of heritability.

The Lizard and the Retriever

We often think of physical traits as being given by the genes, and behavioral characteristics as being supplied by the environment. Indeed, this is the SSSM conception. Some counterexamples from nature show that the division of labor between the physical and the behavioral is not so simple, however.

The Lizard

In California's Mojave Desert, black lava flows are the habitat of an inconspicuous lizard, no bigger than the span of the hand. The lizard is as black as the surrounding lava. A few kilometers away, in the light-colored desert sand, similar lizards of lighter color and more textured pattern thrive. In between, where fingers of lava stretch into the sand, other lizards display an intermediate coloring. These "side-blotched lizards" appear to be a perfect example of animals finely adapted to their environments by evolution, with selective pressures caused by predators that eat lizards of the wrong color, leaving only the appropriately camouflaged ones to reproduce.

On closer inspection, though, some facts don't fit the theory. First, the hatchling lizards in all of these areas look identical. Over a period of months, the lava-dwelling lizards grow darker while those in the lighter environment grow lighter. Second, any animal that evolves into separate, genetically distinct populations should have variability in several features. The side-blotched lizards, though, show variation only in pigment density between groups. Third, a genetically distinct population should be large enough to sustain itself, but isolated croppings of black lava not much larger than the territory of a single lizard can be found in the Mojave, with lizards that show a definite color-matching tendency. The lightest lizards of all, in fact, live in the snow-white dust downwind of a desert cement plant!

These observations lead to an unexpected conclusion: the side-blotched lizard is genetically equipped not to develop a specific coloration but to adjust its color during development to match the surroundings in which it is hatched (Norris, 1967). All of those desert lizards are of the same species—eggs moved from the lava-dwelling group will develop into perfectly normal sand-dwelling lizards, and vice versa. The humble lizard has not merely adapted to its environment but has achieved something much more powerful—it has adapted to adapt to its environment. Not only the inheritance of its genes but also the conditions of its nurture determine the color of the side-blotched lizard.

The Retriever

An example of animal adaptation closer to home is the retriever. When a hunter shoots a bird, the faithful dog scrambles through the underbrush and unerringly brings the prey back in its teeth. To a psychologist who has spent a career training rats, this seems to be a good example of an intelligent animal, the dog, learning to perform a useful function for its master.

But look more closely. Though the hunter knows little of the psychology of animal training, the dog retrieves nonetheless. Retriever puppies start fetching things as soon as they can walk—a stick, a ball, your missing slipper. A retriever raised by humans without ever seeing another dog will retrieve for hours without obvious reward. Though some work is needed to coordinate the dog-human team, their teamwork is built on a behavioral pattern bred into the animal by generations of artificial selection. The dog is born to fetch.

The lizard and the retriever seem distant from issues of the evolution of human behavior, but they yield the insight that most characteristics of animals and humans, whether physical or behavioral, result from intricate interactions of environment and heredity. The gene-environment path is sequential—it's never just one or the other.

The Human as a Biological Organism

How can we determine whether the SSSM is incomplete, whether biological structure is as critical as culture for understanding human nature? One way to approach this question is to put people in perspective, to compare humans with other animals. We can especially compare humans to other primates, most appropriately to chimpanzees, our closest living relatives. We share about 98% of our genes with chimpanzees (Kim & Takenaka, 1996), making humans and chimpanzees about as closely related to one another as horses and donkeys. In fact, chimpanzees are more closely related to humans than to gorillas, our next nearest primate relative. Biologically, we are not a unique end point in an unerring progression from worms to philosophers, but just another animal in another ecological niche. The rules of inheritance are the same for us as for every other creature.

One way to test the SSSM directly is to find out whether genetic inheritance can indeed affect what seem to be social conventions such as mate preference, aesthetic preferences, language, a sense of duty, and many other psychological characteristics of humans. The chapters of this book show that all these things include strong genetic as well as cultural influences. We see similarities in these characteristics in all cultures, and we can find good biological reasons why we have evolved to handle these human challenges in particular ways. In some cases, we can even trace the history of the genes that nudge us along certain paths. And it is usually a nudge that the genes give us, through motivations, attitudes, and aptitudes, not a reflex-like command (Ehrlich, 2000).

In mate preference, for example, we are finely tuned to find the partners who are most likely to provide the resources necessary to raise offspring successfully. Each sex has its own preferences for the opposite sex; the preferences are partly overlapping, partly distinct, and mostly cross-cultural. They can be shown to optimize reproductive success. Most people are unaware that these genetically influenced traits exist, even while their genes profoundly affect their own behavior in this most personal and most important aspect of our lives. The genetic nudges, however, push us in directions that would have been appropriate in the Stone Age, and may or may not lead to wise choices today. Later chapters give the details.

● THE PLACE OF EVOLUTIONARY PSYCHOLOGY

What's different about evolutionary psychology? First, taking evolution into account vastly increases the scientific base on which psychology can build. We can investigate not only who we are but also where we have been, and we can look to the structure of minds and genes to provide insight about human behavior and experience. Genetics, ethology, and a half dozen other disciplines become fodder for the psychological theorist. Furthermore, we have begun to see past the **proximate causes** of much current psychological theorizing to the **ultimate causes**, describing not only how things are but also understanding how they came to be that way.

From language to mate selection, from visual perception to reasoning, evolutionary theory has given us a context, linked us to other traditions, and helped us to ask new questions. Evolutionary theory is not the only tool of the psychologist, though: it is only one of many ways of organizing psychological data and better understanding how the mind works.

● HISTORY OF EVOLUTION IN THE BEHAVIORAL SCIENCES

The idea of evolution by natural selection was developed by two men at about the same time, Charles Darwin and Alfred Russel Wallace. Darwin had been sitting on his explosive insights for nearly 2 decades when he heard that Wallace had developed a similar theory to his own and had independently collected evidence supporting it. Darwin generously offered to cointroduce the idea with Wallace to the Royal Society, but history has given the credit to Darwin and left Wallace as a footnote in Victorian science.

Darwin

One reason for this disparity is that Darwin was a gifted writer as well as a great scientist—his book *On the Origin of Species* (1859) is still worth reading today. Within both the social and biological sciences, perhaps the most significant reason why Darwin is remembered, whereas Wallace is not, is that Wallace didn't go all the way with his theory. He admitted to natural selection for animals and for human physical characteristics, but like Descartes two centuries before, he reserved a special place for human sentience, linking it to a gift from God. Darwin did not stop at the physical, but courageously followed his ideas through to the heart of the human condition, to the mind and its origins.

Objection and Response

One of the reasons why Darwin procrastinated so long in publishing on evolution by natural selection is that he correctly anticipated the firestorm of criticism that it aroused. He also feared that it would offend his wife, Emma, whom he loved dearly and who was very religious. Less visible from the current perspective, though, is the immediate and enthusiastic reception of the idea by most of natural science and medicine of the time. For example, Ewald Hering, a giant of 19th-century German physiology, was incorporating evolutionary ideas in his explanation of the structure of the visual system less than a decade after the appearance of *On the Origin of Species* (Hering, 1868).

The objections came more from the general public, and specifically from religious leaders. A clear differentiation of the domains of science and of religion could have ameliorated this conflict, for there is a principled division between the two domains in the distinction between structure and content. Science explicates the rules by which the natural world works, but it is largely silent on the actual contents of culture—the rich historical and contemporary content of events, ideas, and human interactions. If you want to know the rules in the football game of life, you should ask a scientist. But if you want to know the score, you should inquire of a poet or a writer, a historian or a journalist. Religions had developed their own cosmologies and biologies in the vacuum of the incomplete science of previous centuries, and unfortunately some religious leaders were reluctant to let go of them. Some, especially in more conservative religious circles, still are.

Late in his life, Darwin published two additional books, again both well worth reading even today, that would have earned him an honored place in the history of psychological biology even without his *Origin of Species*. One dealt with the descent of humans (Darwin, 1871), pointing out many similarities between the human and the chimpanzee, and introducing the idea of sexual selection, and the other (Darwin, 1872) began the comparative study of emotional expression in animals and humans. Both contributed to the founding of the science of **ethology**.

Ethology

Twentieth-century field biology, centered in Europe, gave rise to the discipline of ethology, the explication of behavior by biological principles. Ethologists such as Niko Tinbergen (1951) were able to understand reproductive behavior in birds, for example, by analyzing the characteristics of the species. If it takes two parents to feed the chicks until they reach maturity, a stable pair bond will form between the parents. It may last just for a breeding season, or for a lifetime. The mating rituals that establish the bond evolve from already-established patterns of social interaction in the species, usually from either dominance/submission displays or nurturance behaviors. As is typical in evolution, new capabilities arise from old parts.

Konrad Lorenz discovered imprinting in young birds, a specialized form of learning that induces chicks to follow their mothers as soon as they hatch. He showed in a dramatic way that the behavior is learned, by imprinting chicks to follow him, in the process demonstrating that imprinting can occur to a very wide variety of possible objects. At the right time in life, the chicks will follow any large thing that moves, and will remain imprinted on it. It is an example of a simple genetic program that usually produces the desired result without a detailed plan of the mother's characteristics.

Ethologists studied social behavior in a wide variety of animals, but rarely investigated humans. That job fell to a new discipline.

Sociobiology

In 1975, E. O. Wilson published *Sociobiology: The New Synthesis*, a book that founded a field and ignited a storm of controversy. Wilson predicted that psychology would eventually be subsumed within biology. Most of the book was a masterful analysis of social behavior in animals, but in his last chapter, Wilson speculated on the possibility of applying his genetic analysis to human social behavior. Though the applications were mostly speculations about how human behavior might be driven by evolved mechanisms, Wilson was criticized because his speculations were not backed up by empirical evidence. Sociobiologists were accused of telling *just so stories*, after the stories of that name published by Victorian author Rudyard Kipling. The stories describe not how things are, but how things might have happened.

Many psychologists were offended by the idea that evolved adaptations as well as cultural conventions could be regulating human social behavior, whereas other psychologists extended the speculations further. The data weren't yet there to establish the role of biological structure in social behavior—before it really got started, the new discipline fell into disrepute.

Evolutionary Psychology

In the 1980s, a new group of psychologists began to appear, calling themselves evolutionary psychologists and building much of their theoretical stance on Wilson's ideas and on the pioneering work of Robert Trivers. They have done most of their research in social interaction, broadly interpreted, because the theoretical base of psychology seems weakest there. The new field is broader than sociobiology, however, encompassing fields such as thinking, problem-solving, perception, and memory as well as social behavior, putting more emphasis on humans, and engaging life challenges at every level.

While the debates about sociobiology continued to rage, this group began quietly gathering the empirical base on which much of the content of this book rests. Pursuing their goal of putting a new theoretical foundation under psychology, they found at the base of the existing body of psychology a welter of small theories, each plausible in itself but unrelated to the others, and compact descriptions of phenomena disguised as theories. As the empirical base broadens, it has become possible to base psychology more firmly on theory that applies both within and outside psychology, to make psychological theories more consistent with one another, and also to address new problems from the perspective of the new orientation. Most workers in this field are not dedicated to evolutionary psychology as much as to the goal of building evolutionary ideas into all of psychology.

Evolutionary psychology has attracted its own set of critics, though. Their concern is motivated partly by the unhappy record of past attempts to apply evolutionary theory to public life.

● USES AND MISUSES OF EVOLUTION

There is a general rule that all powerful things are dangerous, be they chain saws, televisions, or scientific ideas. Evolution, being a very powerful idea, also proved very dangerous in the wrong hands.

Social Darwinism

As the idea of evolution filtered through Victorian society, it became diluted and distorted. If the more fit are more successful, Herbert Spencer and some others reasoned, then the people at the top of the social heap must be more fit than the others. It was Spencer, not Darwin, who coined the term *survival of the fittest*. The famous saying distorts Darwin's insight that it is not mere survival but reproduction that defines biological fitness, and it implies that the fittest have the right to suppress the less fit.

Nonetheless, the socially powerful seized on the idea to justify their dominant positions and their exploitation of others as a "natural" condition. German philosopher Friedrich Nietzsche extended this to the idea of the *Übermensch*, often mistranslated as "superman" but meaning "dominant person." You can guess who got to be the *Übermensch*.

Since the socially dominant and their apologists spent a lot of effort broadcasting their ideas while scientists quietly went about their empirical studies, only one side was heard, and segments of the public began to associate Darwinism with social exploitation. Part of the reason why the social sciences at their birth rejected biological ideas was in reaction to social Darwinism. Another movement, though, was about to make social Darwinism look benign by comparison.

Eugenics

Throughout history, people have observed that some of their fellow human beings are more capable than others. The human race could be improved, they argued, if only the most capable were allowed to reproduce. We could develop superior humans in the same way that we develop superior dogs or roses, by artificial selection. The idea is formalized in **eugenics**, the effort to produce superior humans by selective breeding. One of its first champions was Charles Darwin's cousin, Francis Galton.

Assumptions of Eugenics

Although the goal of making humanity better through eugenics seemed admirable at first, and was advocated by many idealistic reformers, it is based on fundamental misunderstandings of evolutionary theory. First and most important, it assumes that the genes of one group are by some measure superior to the genes of another. However, everyone in the population stands at the pinnacle of an equally long series of successful reproductions. Traits that we value at the moment are mixed with other less-valued traits in each of us, and sexual recombination will reshuffle them again in the next generation. What is valuable will itself vary from one environment to another, like the lizards' skin pigment example earlier.

What about traits that nearly everyone values, such as high intelligence? If a higher intelligence would have been good for humans, providing superior fitness, the average intelligence level of the population would have drifted up to that level a long time ago, by mechanisms to be described below. There are reasons, that we often don't understand, why average intelligence has settled where it has. Manipulating such traits assumes that we can successfully second-guess millions of years of hominid evolution.

More fundamentally, eugenics has built into it the assumption that some have the right to reproduce more than others, or even the right to prevent others from reproducing. It's social Darwinism writ large. Who has the authority to decide, on what criteria, and with what justification?

Eugenic Experiments

Examples of past efforts at eugenics have thrown these objections into relief, especially the last one. One of the most widespread eugenic experiments was an effort to sterilize the "feeble-minded," which victimized thousands of people in the United States and other countries in the early 20th century.

Other experiments have attempted to increase the fertility of those judged most desirable. Among the largest was a movement called Lebensborn in Nazi Germany, intended to produce babies by unwed mothers. The mothers were not particularly selected, but the fathers were Nazi SS officers—arguably the most aggressive and vicious members of that society. Another experiment, in the United States, encouraged and subsidized families of a group of men also judged to be particularly worthy—in this case, military test pilots. Again, inexplicably, there was no effort to select the mothers. Fortunately, both of these efforts were too small and too short-lived to have had a significant impact on the population.

In the idyllic village of Irsee, Germany, stands another reminder of eugenic efforts. Behind the elegant baroque cloister in the center of the town, a small plaque commemorates about 4,000 occupants of the building, which had been converted into a psychiatric hospital. All of them had been killed by the Nazis and buried in mass graves behind the church. The mounds of earth are still visible.

Genetic Determinism

One of the persistent objections to evolutionary explanations in psychology, and to biological explanations generally, is that if something is found to be genetic, it can't be changed, and therefore it is dangerous to investigate the genetic basis of intelligence, personality, mental illness, and so on. The objection argues that some aspects of the human condition are better left uninvestigated, lest we find something uncomfortable. A gene for alcoholism, for instance, would tell us that some people are doomed to become alcoholics, so we may as well forget about treating them.

Treatment of Genetic Conditions

The history of actual discoveries about genetic contributions to human behavior has revealed the flaw in such arguments. An example is **phenylketonuria** (PKU), a degenerative form of mental retardation. A PKU baby seems normal at birth, but after a few months begins to decline while normal babies are progressing. The parents watch helplessly as the disease progresses, until the child inevitably dies.

The discovery that PKU is caused by a single recessive gene did not cause physicians to abandon efforts to treat the disease, though. Instead, the function of the gene could be found. It turned out to direct the manufacture of the enzyme phenylalanine hydroxylase, needed for the metabolism of the essential amino acid phenylalanine. Without the gene, toxic byproducts of phenylalanine build up in the blood, sometimes to 100 times normal levels, and metabolic derivatives such as phenylpyruvic acid accumulate, slowly poisoning the child (Gardner, 1983).

The discovery of the metabolic defect and its genetic basis led directly to a treatment for the disease. If PKU is diagnosed early in infancy, the progressive mental retardation can be prevented by carefully controlling the amount of phenylalanine in the diet, enough to allow synthesis of body proteins but not enough to allow toxic byproducts to accumulate. Discovery of a genetic basis for PKU led not to hopelessness but to effective treatment.

A more common example is early-onset diabetes, which is also inherited. Discovery of a genetic basis for the disease meant that physicians could stop looking for a virus or bacterium, and get down to the business of compensating for the missing sugar-digesting enzyme. Because its genetic and biochemical basis is understood, diabetes has changed from a sentence of a slow, drawn-out death to an inconvenience.

It is the same with many of the serious mental illnesses reviewed in Chapter 9—knowing the genetic bases of the diseases helps in efforts to control them. The objection to genetically based studies implicitly assumes the SSSM competition model of genes versus environment. But since genes work only through an environment (Figure 1.1), manipulating the environment can modify the effects of the genes.

Defending the Status Quo

A similar objection to evolutionary analyses of the human condition is that they seem to legitimize the status quo. If the genes have determined some aspect of human thinking or human interaction, the argument goes, there is no sense in trying to change it. Better to deemphasize the genetic contribution, lest an unjust social situation become legitimized and perpetuated. Because current social and economic conditions have resulted from an interaction of human environments and the permanent inheritance of our genes, the evolutionary argument must conclude that conditions are what will always be.

In a way, this objection is a leftover reaction to the failed movement of social Darwinism. The fallacy in this stance is similar to that of genetic determinism in dealing with diseases or disabilities, because genes work in environments, and only by understanding the genes can we change our environments in such a way that our genes work for us rather than against us. By knowing how we are made, we can improve our quality of life. The organism that is capable of understanding itself and its place in nature is finally beginning to do so.

Male-Female Differences

The status quo arguments become particularly important, and particularly contentious, when applied to gender differences. Evolutionary analysis tackles the problem of disentangling natural and cultural differences between the sexes by using evolutionary theory to generate hypotheses about natural differences. Darwin recognized that emotions and intelligence would be as relevant to the evolutionary fate of their possessors as would any other traits. When the sexes are considered from this viewpoint, it becomes clear that we expect males and females to have significantly different temperaments because their reproductive needs are so different.

A human female, reproducing flat out, can produce only about one child a year, a limit that does not apply to the male. Thus different psychological characteristics were needed for success in the evolutionary arena. The problem is that many familiar differences between men and women, often interpreted as culturally induced, are turning out to be the very ones that natural selection might be expected to have planted deep in our natures.

Evolutionary reasoning suggests, for instance, that women should be strongly devoted to the care of their children, and should prefer impressive, high-status males from whom they seek undivided commitment. Men should be competitive, adventurous, and motivated to possess women and control their sexuality. They should prefer youth and beauty, but also grasp whatever sexual opportunities present themselves. The specifics are in Chapter 3.

It seems that, after its early promise as an ally of liberation, evolutionary psychology leads back to traditional views. This is why some people object to evolutionary psychology as politically motivated pseudoscience, rife with genetic determinism, gross oversimplification, insensitivity to variation and overlap, categorizing, stereotyping, and rampant sexism.

But the new claims about sex differences, although they may sound like the old ones, are quite different. Some of the traditional ideas are contradicted: nothing in evolutionary psychology suggests, for instance, that women are less intelligent than men. There is also a more fundamental and more subtle point. Even when evolutionary psychology's claims about male and female differences sound like traditional ones, they are not because of the radical change in the idea of nature (Richards, 2000).

Traditional claims about the natures of men and women were made in the context of a long-established view of the world as a naturally ordered whole, harmonious as long as everything stayed in its ordained place. If things went wrong, that was due to interference in the natural order of things. The most familiar version of this approach is the religious view that sees order and complexity as underlain by divine plan. In such traditions, to understand the nature of something is to identify its place in the scheme of things, so that to understand the nature of men and women is to know how they should live harmoniously together.

But evolution by natural selection, which shows in principle how complexity can arise without any design or intention, revealed a very different world without any underlying moral order or natural harmony. In this modern, scientific world, describing the nature of something says nothing about its natural place or what it is good for. It gives only a neutral account of what something is like and how it interacts with other things.

The trouble is that prescientific, pre-Darwinian ideas about nature are so deeply ingrained in our culture that they persist even among otherwise scientifically oriented people. This leads to systematic misinterpretation of the worldview of evolutionary psychology.

In a Darwinian world, for instance, claims about the way evolution has shaped male and female emotions do not imply psychological homogeneity within each sex, or firm boundaries between them. Variation is to be expected, because it is the raw material of evolution. Ideas of fixed essences and clear distinctions between natural kinds belong to earlier interpretations of an ordered universe.

Similarly, claims about sex differences cannot imply genetic determinism. To say that men and women are different by nature does not say that their development and actions are fixed in their genes; it implies only that they are likely to react in different ways to similar environments. Recall that the genes offer nudges, not commands. The idea that natures are immutable also belongs to the pre-Darwinian world and is irrelevant to evolutionary psychology.

Most important, discoveries in a Darwinian world about the natures of the sexes have no direct implications whatever for how they should live and relate to one another. There is no reason to expect their interests—either evolutionary or personal—to coincide. Natural selection produces harmony only to the extent that harmony promotes reproduction, for evolutionarily speaking, the sexes are rivals.

Paradoxically, the same mistake shows even in the apparently opposed idea that Darwinism justifies constant struggle. But interpretations of evolution as all-purpose progress also depend on the idea of a natural order through which evolution progresses. Darwinian evolution has no such onward-and-upward path. The only hope for progress lies in deciding within our culture what counts as progress, and then trying to bring it about.

By whatever standard, we cannot progress without understanding what we are up against. If science indicates that men and women are different, that is something we need to know. We do not need resistance that comes from encumbering Darwinian insights into human nature with relics of a pre-Darwinian world (Richards, 2000).

These are the claims and counterclaims. To evaluate them scientifically requires a look at the nuts and bolts of evolution.

● HOW EVOLUTION WORKS

The process of evolution is built into the most fundamental machinery of life itself—the genetic material and its inheritance. Once the basic mechanisms are described, the workings of evolution will be obvious. All the chemical reactions that make up living things are based on directions from the genes, the molecular instruction codes in the nucleus of each cell. To understand evolution, we will begin by zooming down from the level of organisms to the level of the macromolecules that direct the processes of life.

Genes

Genes themselves are made up from strings of DNA, a molecule that can form into pairs of long chains with a double helix structure (Figure 1.2). Each chain consists of a series of organic molecules bonded together one after another. Because each molecular chain has a long "backbone" of identical units, they are called **polymers** (poly = many). There are four types of molecules that bridge between the two chains: they are the organic bases adenine (A), thymine (T), guanine (G), and cytosine (C). It happens that A and T have complementary shapes, so that they bond to each other across the gap between the two helical backbones of DNA. Each base has two electrically charged regions that match charged regions in the other, so that a pair of hydrogen bonds (relatively weak chemical bonds) links the two molecules together. G and C have a similar compatibility, but with three hydrogen bonds linking them.

In a genetic DNA molecule, these four bases string together like a four-letter alphabet, encoding the information that a living cell eventually uses to direct the production of proteins. When the information is read, the DNA is uncoiled, breaking the hydrogen bonds between **base pairs**, so that the order of the pair in the DNA double helix (A-T or T-A, for example) makes a difference in what information is represented.

Because there are only four letters in the genetic alphabet, it is possible to measure the amount of information that genes can carry. The smallest unit of information is the **bit**, a two-alternative choice where each choice is equally likely. Each base pair contains exactly two bits of information, because I would have to ask you two yes/no questions to find out which of the four bases occupies a given location. First I would ask whether the location in question contained an A-T pair or a C-G pair. Then I would ask whether the

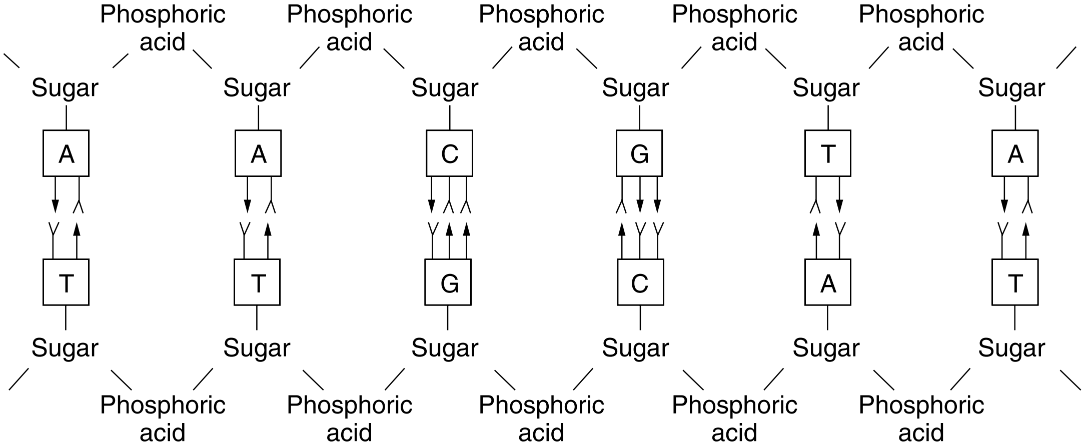

Figure 1.2 Structure of the DNA molecule, showing the four bases that line up to create base pairs.

base was A in one case or C in the other (Figure 1.3). The two questions define two bits of information. So the number of bits of information in the genes is twice the number of base pairs.

How many base pairs are there in the human genome? The number is known, and here is one way it can be determined. Because we know the molecular structure of DNA down to the last atom, we know the molecular weight of a section of DNA that contains one base pair. We take a sample of cells, strip away all the membranes and other structures in the sample, and purify the DNA, removing all the proteins that normally coat its surface. Then we simply weigh the sample and divide by the molecular weight of a base pair and the number of cells that went into the sample. The result is that human genes contain about 3 billion base pairs. At two bits per base pair, this works out to 6 billion bits of information.

Six billion seems like a large number, but the bit is a very small unit. Computer scientists usually measure information in bytes, consisting of eight bits. For large numbers the bytes are combined, a million at a time, into megabytes. So the 6 billion bits in the human genome work out to about 750 megabytes. The hard drive in my desktop computer can hold many times this amount of information. And compared to the trillion or so cells in your body, the number is very small indeed. Later we shall see some tricks that nature uses to squeeze a large amount of structure from a small amount of genetic information.

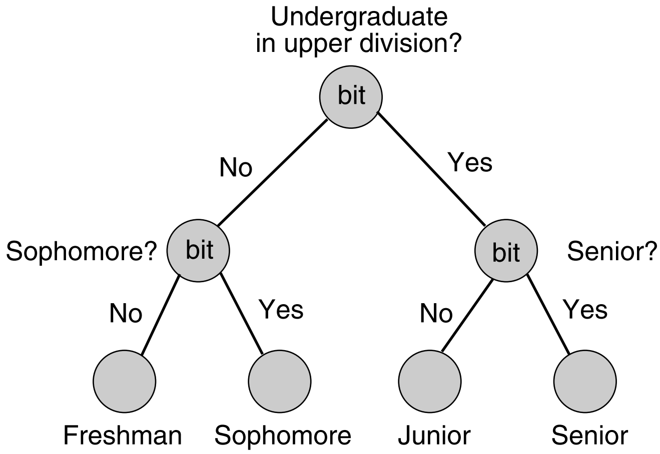

Figure 1.3 Deciding a multialternative problem with a series of binary choices. Each choice requires one bit of information. Extending this logic, one can decide among 2^n choices with n bits.

From Genes to Bodies

How do these wisps of DNA construct a body? This is the domain of embryology, encompassing some of the enduring mysteries of biology.

Individual genes have no body plan built into them, because each gene can do only one thing—to direct the construction of a specific protein molecule. In short, we don't know the details of how bodies are constructed from genetic instructions. But we do know the first steps in the process. The base pairs of the DNA polymer chain are grouped into threes: each triplet codes for a particular **amino acid** (amino acids are strung together to make up proteins). There are $4^3 = 64$ possible triplets of A, T, C, and G, but only 20 different amino acids, so the code is redundant. Both TTT and TTC, for instance, code for the amino acid lysine. And there are three different codes that mark the end of a gene.

Normally, the DNA is covered with specialized proteins that prevent the genetic material from being read out. When these proteins are removed, a segment of DNA can uncoil and pair up with a strand of **RNA** (ribonucleic acid), a molecule similar to DNA but with a different sugar in its backbone. This RNA carries a copy of the genetic instructions out of the nucleus, where the DNA resides, into the cell body, where a **ribosome** transcribes the RNA into a protein. The ribosome is like a complex biological zipper—it reads the

RNA, triplet by triplet, and constructs the corresponding protein according to the three-letter codes for amino acids. The protein is just a string of amino acids chained together, echoing the corresponding chain of RNA. The structure of the protein chain allows it to twist and fold in complex ways, giving it the properties that make it biologically useful.

Reproduction in Cells

When a cell divides, its DNA separates along the line of hydrogen bonds that joins the base pairs. Each base picks up a new complementary base, and a new DNA backbone, to make up two new strands of DNA (Figure 1.4). Each is a replica of the original, and each migrates to one of the new daughter cells. In the process of sexual reproduction, though, there is a different sort of replication. The two coils of the double helix divide into single helices, without picking up new base pairs. Each part is a single strand of unmatched base pairs. These single DNA strands become the genetic material of an egg or sperm cell. When egg and sperm unite to form a new organism by sexual recombination, the DNA from the two parent cells comes together. New double-strand DNA is made, some of it duplicating from the egg's single strands, and some from the sperm's single strands. Once the DNA from the two parents is recombined, it directs the construction of a new organism, complete with all the brain structures that will influence emotions, motivations, instincts and capabilities.

The recombining of genes in a new organism is not quite random, for human genes are aligned on 23 pairs of **chromosomes**, continuous chains of DNA containing sequences of genes, and also including DNA that does not code for production of proteins. If two genes are on different chromosomes, their inheritance will be independent—knowing the identity of the parent who contributed one gene will not help in predicting which parent contributed the other gene. But if two genes are close together on the same chromosome, it is likely that both came from the same parent.

Once the human genome had been sequenced, identifying in order all the base pairs of human DNA, one would think that it would be a simple matter to count the number of genes. It isn't. One can't simply count the number of start sequences in the genome, for instance, because some start sequences are followed immediately by end sequences. Other regions repeat the start sequence over and over. Still other sequences are perfectly good genes that are never expressed in the organism. What had seemed an elegant, clean system turned out to be a mess. As a first estimate, the human genome project revealed that the number of human genes is smaller than the 100,000 or so that had been expected (The Genome International Sequencing Consortium, 2001). Early estimates maintained that the entire

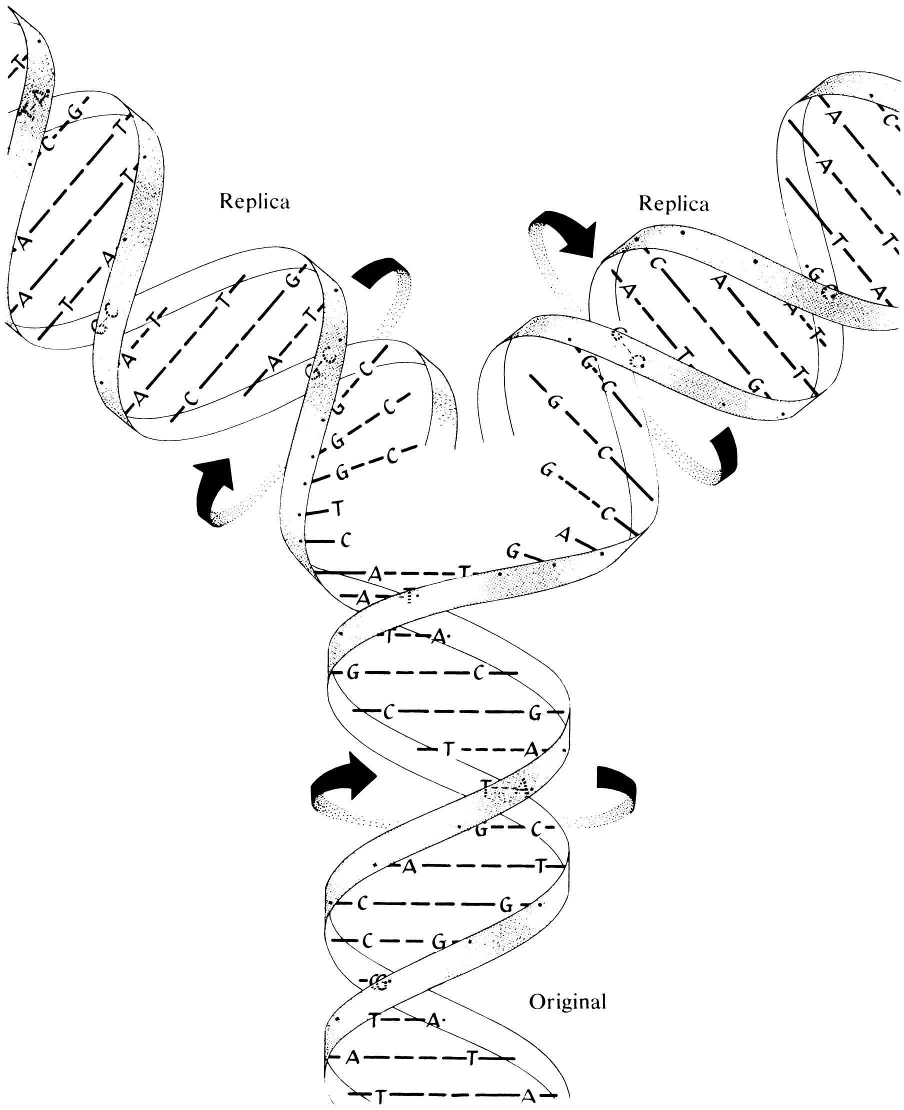

Figure 1.4 Replication, creating two helical DNA strands from one.

human body and brain are based on only about 30,000 genes, and most of the 3 billion base pairs are “junk” DNA that does not code for the production of proteins. Later revisions estimate two to three times as many genes. It will take a lot of careful work to identify the sequences that actually represent working genes.

Reproduction in a Population

Most of the genes that make up a human are the same for every member of the species. Some, including those that direct such basic design features as our bilateral symmetry and our repeating patterns of ribs and vertebrae, are common to nearly all multicellular animals. Others code for such features as the structure of the eye, the enzymes of the liver, and the lobes of the brain. But of our 3 billion base pairs, about 2.5 million differ from one individual to the next, reflecting one difference for every 1,200 base pairs (Cann, 2001). Because these base pairs make up genes that produce characteristics of the organism, they affect the success of that organism in its life in the natural world. It is these differing base pairs that constitute the raw material of evolution.

In a particular environment, one variety or **allele** of a gene may make its carrier more successful than other alleles of that gene that are carried in other individuals. The person who is the carrier of that gene will tend to do better in life and to produce more surviving offspring than people without the superior allele. For example, a gene that provides resistance to a disease will tend to make the carriers of that gene more successful. In Darwin's term, these carriers will have greater biological **fitness** than other people.

Over many generations, the genes of those with the greatest fitness will come to dominate the population, and the genes of the less fit will tend to disappear. This is the basic mechanism of Darwinian evolution by **natural selection**. It is an inevitable result of the facts that genes vary, genes make proteins, proteins influence the traits of an organism, and different traits mean that individuals have differing fitness. Natural selection is the increase in numbers of the individuals with greatest fitness, due to their ability to survive in the natural world.

People often speak about the evolution of a culture, or the evolution of the automobile, and so on. In this book, for the sake of clarity, the word *evolution* will be restricted to its Darwinian sense of evolution by natural selection. It is a change in genes or gene frequencies across generations, through the influence of the environment.

The effectiveness of an allele depends both on what the gene does and on the environment in which it acts. For instance, the genetic mutation that produced the lightness of Europeans' skin has been traced back to a single individual somewhere in northern Europe about 30,000 years ago. Before humans invaded Europe, their dark skin pigmentation was a vital defense against damage from the sun's ultraviolet radiation (Robins, 1991). But as anyone who has spent any time in northern Europe can attest, getting too much sun is the least of one's worries in the northern climate. Rather, people with darker skin cannot produce enough vitamin D from reactions in their skin to avoid rickets, a vitamin-D deficiency disease (Branda & Eaton, 1978). Rickets distorts the skeletons of growing children and reduces their biological fitness.

As a result of this mutation, light-skinned mutated individuals and their descendants had greater fitness; they could have more successful children. The mutation that would spell disaster in the tropics spelled survival in the north. Now, after millennia of cultural adaptation and a few fortuitous mutations, the descendants of those lightly pigmented Europeans have turned around and colonized California, where they tend to get skin cancer.

Biological fitness does not depend on one's physical fitness, as in well-toned muscles, and it is not measured by how much one possesses of such virtues as intelligence, social skills, trustworthiness, kindness, or other valued traits. It is based on one thing, and one thing only—the number of offspring one has. A person with a rich array of valued traits, but who has no children, has no biological fitness by this definition. If someone has high fitness, with many surviving offspring, then the genes of that person will be more strongly represented in the next generation.

Inclusive Fitness. There is another way for one's genes to get into the next generation, and that is through one's relatives. My brother shares half of my variable genes, so that each of his children carries half as much of my genetic inheritance as one of my own children. Because genetic fitness must include these relatives, the idea of **inclusive fitness** (Hamilton, 1964) means that the success of my relatives increases the fitness of my own genes in proportion to the closeness of the relation. Inclusive fitness explains an otherwise incomprehensible statement, "I'd lay down my life for five cousins and a brother." In genetic terms, each cousin shares one eighth of your genes, and the brother one half, so together this group of relatives possesses more of your genes than you do.

This applies only to the 2.5 million variable base pairs, of course—for the rest of the 3 billion base pairs, it doesn't matter how many children one has, for everyone in the next generation will have the same alleles of those genes in any case. Alternatively, some genes are represented by several alleles that are equally effective in doing their job, so that there is no advantage of having one allele over another.

Mutation Versus Recombination. There are two ways that DNA can change to produce individuals of particularly high fitness. One is by **mutation**—a cosmic ray, a poison from the environment, or a mistake in DNA replication can change a base pair at random, thus modifying the protein that is eventually produced. Usually, the mistake makes things worse, because it took billions of years to get it right in the first place, and the unfortunate possessor of the mutated gene has a lower fitness. We have molecular DNA repair mechanisms to keep these changes to a minimum.

Once in a great while, however, a lucky accident occurs, and the mutation creates a protein that does its job better, increasing the fitness of its possessor. The mutation that reduced the skin pigment melanin in our northern European is an example. Then the altered gene can spread through the population because of the greater fitness of its possessors. Statistically, each of us has a small number of mutations, usually affecting less than 20 out of our thousands of genes, and most of them don't have dire consequences one way or the other.

The second way that fitness can be changed is by **recombination** of existing genes. In sexual recombination, it is possible for two or more genes from the two parents to cooperate, working together in new ways. And the genes get reshuffled in every generation. Because most human traits are influenced by more than one gene, this mechanism allows for a healthier or more capable individual of greater fitness. The process is much faster than mutations at changing fitnesses, for nature does not have to wait for the right mutations to come along. As soon as the right gene combination appears, the inheritor of that combination can have increased fitness (more children) right away, and the children who inherit that combination of genes will also be more successful. Again, the combination will tend to spread through the population, and evolution will take place.

The process of gene change in a population, driven by natural selection, takes a very long time, because the change in fitness that a particular gene or gene combination imparts is usually very small. There might be only a tiny chance of raising an extra child because of a beneficial gene combination, or a small chance of raising one child fewer because of an unlucky combination or mutation. The small influence of the gene or genes might take many generations to make its influence felt in the population as a whole. The influence will be felt more quickly if the population is small, because the genes do not have to diffuse through very many people to alter the population. As we shall see, this was the case through most of the period of human existence.

The process of change cannot work miracles, though. Each change is very small, compared to the vast number of unchanged genes and gene combinations in each of us. And nature cannot make investments, putting together elaborate combinations of genes to eventually produce a genetic superman or superwoman. The recombinations and mutations have to succeed in every generation, or at least not get in the way, to contribute to the next. If it turned out that a totally different body plan would serve us better (for instance, four legs and two arms), we would simply be out of luck, for that radical a change is too much for evolution to manage. We shall see in later chapters that many human traits are clumsy constructions that are more or less functional, but could have been done better. In the words of Richard Dawkins (1986), evolution is a "blind watchmaker" putting things together at random and keeping what works.

All of these ideas—influence of genes on human traits, variable fitness resulting from those traits, resulting changes in gene frequency, and the biological mechanisms that drive these changes—sum into a set of concepts called **evolutionary theory**, the application of evolutionary ideas to understanding the design of organisms. Because according to evolutionary principles most of our traits are adaptations that best fit us to our environments, evolutionary theory tells the story of the acquisition and modification of those traits during the course of human evolution. The design of the human organism is based on thousands of adapted traits, some affecting the body and others affecting behavior, each tuned by thousands of generations of natural selection.

● GENETIC MECHANISMS OF EVOLUTION

The processes that we have examined so far belong to "classical" mechanisms of genetic change, those described by Gregor Johann Mendel in the 19th century (he knew about the combinatory processes, but not about the molecular mechanisms). Geneticists have identified several other mechanisms and properties of gene change, however, that can alter the rules in ways that are sometimes surprising.

Genetic Drift

Normally, it is small differences in biological fitness that drive changes in the gene frequencies of a population. But luck is involved as well. Suppose, for instance, that one of your relatives inherits a supereffective combination of genes that makes them likely to have a large and prosperous family. From there, the superior genes should spread rapidly through the population. Just before reaching adulthood, though, your superperson relative is hit by a truck in a tragic but random accident. The gene combination, and its high fitness potential, is lost to the population.

In a small population, the process can also work the other way. Some random trait that doesn't affect fitness, such as long earlobes or a particular shape of nose, might spread through a population by a series of lucky reproductive accidents. The process can even work for slightly disadvantageous genes. Humans may have lost their capacity to synthesize vitamin C in this way, for instance. The phenomenon, **genetic drift,** does not depend on Darwinian fitness but only on chance. It turns out that genetic drift can work only in very small, reproductively isolated groups; if a group grows from a few dozen to even a few hundred reproducing individuals, the mathematics quickly become hopeless, and drift no longer has much effect. The likelihood of any trait spreading at random becomes vanishingly small.

Linking of Traits

A quirk of genetics generates another exception to the rule that nature tends to select genes that confer increased fitness on their owners. Ideally, genes are reassorted randomly in each new individual, so that each gene is favored by natural selection to the degree that it increases overall fitness. But we already saw that those genes that happen to be located close together on the same chromosome are more likely to be inherited from the same strand of DNA, contributed by one parent. This means that if a gene is particularly useful, endowing its owner with increased fitness, the genes near it on its chromosome will tend to be selected as well. These hitchhiking genes may be neutral, or even slightly harmful, but they will continue to spread in a population if the **linking** is strong and if the benefits of the "good" gene outweigh the costs of the "bad" ones. They come along for the ride in a kind of genetic coattail effect.

Fixation

Sometimes a gene becomes so common due to either natural selection superiority or genetic drift that it replaces all the other alleles of the gene that formerly existed in a population. Now that gene no longer shares any of the 2.5 million variable base pairs, but is made up from the 3 billion that are immune from selection pressures. It is no longer a quirk of some people that is not shared by others, but becomes one of the design features of the human species. The now-frozen trait is **fixated**; the species is committed to it, and the only way to change it is through mutation. To know the number of eyes a person has, for instance, I don't have to know their talents, penchants, tendencies, abilities, vocations, or the race of their ancestors. Because this is a fixated trait, all of those things are irrelevant. The person will have exactly two eyes, no more and no less, no matter what.

Most human traits are fixated in this way: only a relatively small number of traits, and the genes behind them, are free to vary. Whether a trait seems fixated or not can depend on the reference group; if you are Chinese, for example, black hair is a universal and fixated trait. At the beginning of human evolution, when there were probably only a few hundred of us, many traits might have become fixated by chance.

It is possible that the turned-down nose of humans, for instance, became fixated from the many variations presumably present in the common ancestor of chimps and humans. A few modern chimp noses look rather like human noses, whereas most look quite different. The range of variation in human noses, like the variation in human genes, is much smaller than that in chimpanzees.

Other traits began as fixated but later acquired variability. It is the variable traits that give humanity its diversity. Hair color, earlobes, eye color, curliness of hair, and shape of the nose are some of the obvious traits that can vary. Perhaps more important are variations in hidden properties, such as capabilities of the immune system or of the brain that give us different mixtures of health, temperament, intelligence, and personality.

There are actually two ways that a trait can be fixated. It can either be controlled by genes for which there is only one allele in all humans, or the trait can be controlled by one of a family of genes that all produce the same result, a phenomenon called **canalization**. Several genetic paths all produce the same phenotype. Particularly important traits are sometimes coded redundantly in the genome, so that if you don't get the trait from one gene, you will get it from another. If the environment varies, one group of these genes or another will guarantee that you express the trait. The strict definition of canalization requires that different genotypes all lead to the same phenotype on the canalized trait. As evolution makes sure that everyone gets the vital traits, they become canalized along with a host of incidental traits.

Punctuated Equilibrium

Darwin thought of evolution as a long, continuous process, with populations constantly evolving into new forms in response to new challenges. Because fossil remains of extinct species are few and far between, it seemed in Darwin's day that every fossil that was found represented a unique stage in a continuous evolutionary process. Now that the fossil record is much better known, some exceptional locations have been discovered where we have an almost continuous record of fossils reaching back for millions of years.

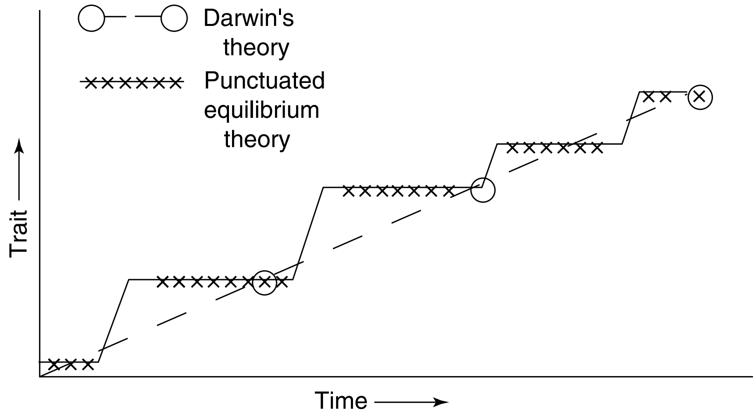

Figure 1.5 Comparison of Darwin's conception and punctuated equilibrium theory. The trait on the vertical axis might be the size of an animal, the complexity of its brain, or some other feature.

An example of such a record is in several African lakes, where small aquatic snails leave their shells on the lake bottom when they die. Some lakes have layers of shells many meters thick, so that biologists can study the forms and colorations of the shells over thousands of successive generations. Not surprisingly, the shells changed as the snails evolved over millions of years. But the change was not continuous. Instead, the snails remained identical from one generation to the next over many generations. Then, abruptly, a new form would replace the old one, and it too would go unchanged for a long period (Figure 1.5). Most of the time the species was not changing. Then for some reason—random genetic events, a new predator, climate change, or some other challenge from the environment—the species quickly evolved into a new form.

During the periods of stability, the snails were in equilibrium with their environment. The most successful alleles of every gene were the most common ones, and any deviation was selected against. The exceptional periods, when evolution was changing the characteristics of the snails, were short compared to the periods of equilibrium, so the periods of rapid evolution were colorfully termed **punctuated equilibrium** (Eldredge, 1985). Even the punctuations, though, might last hundreds or thousands of generations, and are still very gradual when one looks from one generation to the next. The punctuations seem abrupt only in relation to the millions of years that the snails have existed unchanged. During equilibrium, which is most of the time, natural selection does not cease. It continues as vigorously as ever, but now it serves only to maintain the existing form, weeding out deviants.

Punctuation and the Tyranny of the Average

What does all this have to do with the human situation? It means that most human traits are in a state of equilibrium, where the mean of the population also reflects the greatest biological fitness. One can argue about whether humans are evolving at present; but even during a period of punctuation, only a few of an organism's traits change while the rest remain stable. So this means that most, perhaps all, of our traits are at an equilibrium where the average trait is also the best adapted one.

Here, evolutionary theory leads to a startling and counterintuitive conclusion: it is not the exceptional person who is the most fit, but the most average. Though this conclusion violates many peoples' intuition, it is easy to prove. Suppose for a moment that people who are exceptional in a certain trait, say high intelligence, are more biologically fit than people of average intelligence. Intelligent people would leave more offspring in each succeeding generation, until the intelligent people dominated and they became the new average of the population. After that, it would be people of average intelligence (intelligent children of their successful intelligent parents) who would have the greatest fitness. Now the tables are turned—people more intelligent than the new average will have so many problems that their extra intelligence will reduce their fitness relative to those of the new average intelligence. So it is with all traits: the population evolves until the traits that yield the greatest fitness are also the average of the population. When the population reaches equilibrium, the average confers the best fitness.

Empirical Tests of Punctuation in Humans

Because the predictions of this theory seem so peculiar, it is important to investigate it empirically. A theory is useful if it predicts things we otherwise wouldn't have thought to look for, or explains things that otherwise seem mysterious. In this case, a demonstration of the consequences of equilibrium theory comes from studies of physical attractiveness. People are quite consistent in rating the physical attractiveness of others, even from photographs, a capability that is culturally universal (Richardson, Goodman, Nastorf, & Dornbusch, 1961). We might expect some exceptional people to be judged as particularly beautiful, people far from average. This idea can be tested.

In one study, a group of college students judged the attractiveness of a group of women, on a scale of 1 to 10, from photographs in their college yearbook. Then the psychologists running the study used a program to combine faces together, a process called *morphing* in computer graphics. They morphed 2, 4, 8, and more faces together. When they got up to a composite of 32 faces, they presented the resulting image to the original judges and had them judge that face also. The result was that the composite face was judged to be more attractive than any of the faces that were morphed into it (Cunningham, 1986). As you can imagine, the experiment caused an uproar when it first appeared, but the result has been replicated (Langlois & Roggman, 1990) and appears to be solid.

How can this be? According to punctuated equilibrium theory, the average traits should be the most desirable because they confer the highest fitness, and we would expect humans to be most attracted to partners with the highest potential fitness. Thus the theory predicts that people with the highest attractiveness should not be the unusual, but the most average. And when you look at the morphed composite (Figure 1.6), you may find her to be quite attractive, just as the subjects in the study did. Alas, you will never meet her. She exists only in a computer, a concatenated ideal who is average on more traits than any real person.

This does not mean that the average of any group of people will always be perceived as the most attractive, however. The group from which the sample was taken may have included many people who were not at the peak of their own attractiveness. The average of a group of people in their eighties, for instance, will produce a particularly attractive eighty-year-old. The average appearance can be enhanced by adding features that normally are considered attractive, such as those that signal youth or fertility.

Preferences are one thing, but actual behavior is quite another. Throughout this book, it is important to look beyond perceptions and preferences to see how adapted traits affect human actions. Because punctuated equilibrium predicts that average people should be the most successful reproductively, the theory can be tested by looking at reproductive behavior.

A survey that probed both the number of children a woman had and her socioeconomic status (SES) showed that the highest-status women were not the most successful reproductively (Hewlett, 2002). In the United States in the 1990s, one third of high-salary career women were still childless at age 40. The lowest-SES women were also less successful, because of higher mortality in the poorest groups. The women with the largest proportion of surviving children were those who did not go to college, but who married working-class men and started their families early. It was not the highest- or the lowest-SES women, but a group somewhere in the middle that was most successful reproductively, just as punctuated equilibrium theory predicts.

Figure 1.6 Effect of morphing many female faces together. The large photo is a computer-generated composite of all the faces in the small photos.

Exceptional success in education or careers does not necessarily translate into Darwinian fitness.

The average-is-best property, of course, applies only during periods of equilibrium. A population in a period of punctuation is a population in crisis, when the dominant traits are not the best ones, and exceptional individuals are being selected. For modern humans, such a crisis occurred over a period of probably tens of thousands of years, ending about 100,000 years ago.

Sexual Selection

Evolution normally selects traits that enhance an organism's ability to cope with its environment. Adaptations such as good visual acuity, fine motor coordination, and ability to work with a group can clearly evolve by natural selection, because people who are strong in those traits are more likely to survive and prosper than those who are weaker in the traits. In order to pass the genes supporting these traits along to the next generation, however, an organism must jump one more hurdle—it must find a mate and reproduce. Mating becomes the final common path through which all the other traits, good or bad, are funneled. Without a mate and a successful reproduction, all the other traits count for nothing.

Charles Darwin recognized the need for **sexual selection**, the selection of animals that successfully reproduce. It generates an exception to the rule that adapted traits should enhance the ability of an animal to survive, because sexual adaptations are directed toward the preferences of potential mates rather than toward the challenges of the environment.

We chuckle at the male peacock, with its absurd overdevelopment of tail feathers that evolved to attract the peahen. Because the peahen is attracted to the male with the biggest and most colorful display, the males with the most elaborate displays are the most successful in mating. The destabilizing factor is that, given the choice, the hen prefers not the average display but the biggest and gaudiest (Houle & Kondrashov, 2002).

The biggest display signals the best genes. Eventually, nature sets a limit on the size of the display when the male can no longer fly and is easily caught by predators before it can transfer its genes to the next generation. So the peacock's display becomes as large as nature can contrive, driven by the female's preference for large displays.

Ridiculous though the peacock example may seem, humans have some similar characteristics. When asked to pick which female profile is most attractive, for example, men generally pick a profile with larger-than-average breasts, violating the rule from punctuated equilibrium theory that the average should be preferred. We don't know how much this is a product of current fashion, or whether the same preference would have appeared 1,000 or 10,000 years ago, but we have no reason to suppose that a survey of our distant ancestors would have turned out very differently.

This brings up two questions. First, why do men prefer larger breasts? One answer is that large breasts are a sign of sexual maturity, and it is better to be sure about that than to rely on subtle signs. Second, given that large breasts are preferred, why don't women evolve larger breasts? Again there is a compensating factor, for it is impractical to carry them around, especially for a Paleolithic nomad, so the benefit of large breasts in sexual attraction is balanced against their cost in energy and agility. Nature finds a compromise, of course with individual variation as well.

In the spirit of equality, consider a similar example that goes the other way. Women prefer men who are taller than average. We can explore this preference not only through surveys but even by analysis of personal advertisements in newspapers (women seeking men). When a preferred height is mentioned, a woman almost always requests a taller-than-average partner (Pawlowski, Dunbar, & Lipowicz, 2000). Furthermore, height is correlated somewhat with status in men.

Does all this make a difference in reproductive success? There is now evidence that it does. A survey of Polish and British men revealed that on average, the taller men in both cultures had more children than shorter ones. Furthermore, childless men averaged 3 cm (1.2 in.) shorter than men with at least one child, and bachelors averaged about 2.5 cm (1 in.) shorter than married men. Pawlowski, Dunbar, and Lipowicz (2000), who did the research, undertook the study after they noticed that men in personal ads (men seeking women) advertised their height only if they were tall.

If this is so, why doesn't natural selection make men taller and taller, until the tall men are average? The answer again is a compromise, this time between the desirability of height and the practicality of balancing on two legs, which limits the height of men. Almost all of the tallest men have trouble with their knees before retirement age, and there are circulatory problems as well. So again, a sexual preference that deviates from the average keeps a trait pushed against a ceiling, in this case almost literally.

This doesn't necessarily mean that humans are evolving to be taller, though. To be exceptionally tall means that everything during development has to have gone right, including inheriting reasonably appropriate genes, an unproblematic pregnancy, optimal nutrition as a child, and so on. A tall phenotype isn't dependent entirely on a tall genotype.

Though some cross-cultural work has been done on these questions, most of the studies investigate European populations. A broader sample of cultures would strengthen and generalize the conclusions.

Sexual selection, like other kinds of selection, has always been a part of human life. The beginning of humanity ushered in the **Paleolithic** era, or *old stone age* (Greek *paleo* = old, Greek *lithic* = stone), a world so different from today's human environments that it is difficult even to imagine what life must have been like then. But because it is the world to which humans are adapted, we will have to examine it closely to understand what we are like. This is the subject of the next chapter.

● DISCUSSION QUESTIONS

1. Why do you think some scholars resist the idea that biological structure and evolution are important in understanding human life?
2. Is the present human population evolving? If so, how?
3. If natural selection tends to optimize traits, why do we have strange characteristics such as sweat glands that let us drip with sweat (wasting water) and excrete salt (wasting salt)?

FURTHER READING ●

Alcock, J. (2001). *The triumph of sociobiology.* Oxford, UK: Oxford University Press.

John Alcock, a leading expert in Darwinism and animal behavior, explains why there was so much objection to E. O. Wilson's book *Sociobiology.* Many rejected Wilson's ideas not because they were demonstrably wrong, but because the moral implications were uncomfortable. Alcock dissects moral from scientific knowledge, asserting that those who would improve moral behavior should first understand its basis.

Darwin, C. (1859). *On the origin of species.* London: Murray.

The founding book of evolution by natural selection is still in print, still readable, and still fascinating in the power of its insights and the wealth of the evidence that Darwin assembles in defense of his theory.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The Adapted Mind*. New York: Oxford University Press.

Two leaders of evolutionary psychology lay out the SSSM, its shortcomings, and the alternative that evolutionary theory offers. The article appears in a volume that has become the bible of evolutionary psychology.

Wilson, E. O. (1975) *Sociobiology: The new synthesis.* Cambridge, MA: Harvard University Press.

Edward O. Wilson's masterful synthesis of material on the biological basis of social behavior founded a new discipline and is still worth reading. It links psychology with animal ethology, enriching both disciplines.