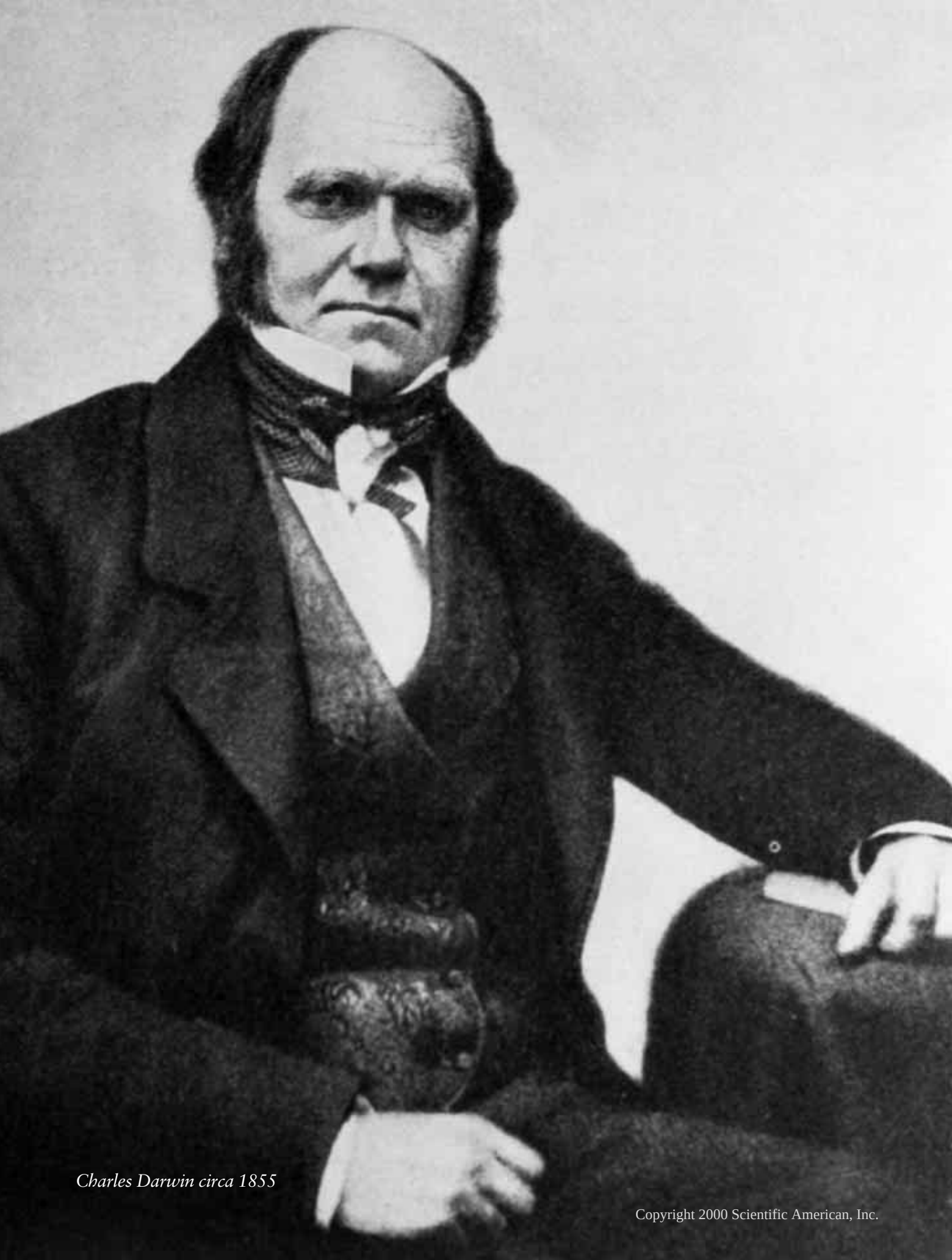

Charles Darwin circa 1855

Darwin's Influence on Modern Thought

by Ernst Mayr

Great minds shape the thinking of successive historical periods. Luther and Calvin inspired the Reformation; Locke, Leibniz, Voltaire and Rousseau, the Enlightenment. Modern thought is most dependent on the influence of Charles Darwin

Clearly, our conception of the world and our place in it is, at the beginning of the 21st century, drastically different from the zeitgeist at the beginning of the 19th century. But no consensus exists as to the source of this revolutionary change. Karl Marx is often mentioned; Sigmund Freud has been in and out of favor; Albert Einstein's biographer Abraham Pais made the exuberant claim that Einstein's theories "have profoundly changed the way modern men and women think about the phenomena of inanimate nature." No sooner had Pais said this, though, than he recognized the exaggeration. "It would actually be better to say 'modern scientists' than 'modern men and women,' " he wrote, because one needs schooling in the physicist's style of thought and

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mathematical techniques to appreciate Einstein's contributions in their fullness. Indeed, this limitation is true for all the extraordinary theories of modern physics, which have had little impact on the way the average person apprehends the world.

The situation differs dramatically with regard to concepts in biology. Many biological ideas proposed during the past 150 years stood in stark conflict with what everybody assumed to be true. The acceptance of these ideas required an ideological revolution. And no biologist has been responsible for more—and for more drastic—modifications of the average person's worldview than Charles Darwin.

The testing of historical narratives bridges science and the humanities.

Darwin's accomplishments were so many and so diverse that it is useful to distinguish three fields to which he made major contributions: evolutionary biology; the philosophy of science; and the modern zeitgeist. Although I will be focusing on this last domain, for the sake of completeness I will put forth a short overview of his contributions—particularly as they inform his later ideas—to the first two areas.

A Secular View of Life

Darwin founded a new branch of life science, evolutionary biology. Four of his contributions to evolutionary biology are especially important, as they held considerable sway beyond that discipline. The first is the nonconstancy of species, or the modern conception of evolution itself. The second is the notion of branching evolution, implying the common descent of all species of living things on earth from a single unique origin. Up until 1859, all evolutionary proposals, such as that of naturalist Jean-Baptiste Lamarck, instead endorsed linear evolution, a teleological march toward greater perfection that had been in vogue since Aristotle's concept of *Scala Naturae,* the chain of being. Darwin further noted that evolution must be gradual, with no major breaks or discontinuities. Finally, he reasoned that the mechanism of evolution was natural selection.

These four insights served as the foundation for Darwin's founding of a new branch of the philosophy of science, a philosophy of biology. Despite the passing of a century before this new branch of philosophy fully developed, its eventual form is based on Darwinian concepts. For example, Darwin introduced historicity into science. Evolutionary biology, in contrast with physics and chemistry, is a historical science—the evolutionist attempts to explain events and processes that have already taken place. Laws and experiments are inappropriate techniques for the explication of such events and processes. Instead one constructs a historical narrative, consisting of a tentative reconstruction of the particular scenario that led to the events one is trying to explain.

For example, three different scenarios have been proposed for the sudden extinction of the dinosaurs at the end of the Cretaceous: a devastating epidemic; a catastrophic change of climate; and the impact of an asteroid, known as the Alvarez theory. The first two narratives were ultimately refuted by evidence incompatible with them. All the known facts, however, fit the Alvarez theory, which is now widely accepted. The testing of historical narratives implies that the wide gap between science and the humanities that so troubled physicist C. P. Snow is actually nonexistent—by virtue of its methodology and its acceptance of the time factor that makes change possible, evolutionary biology serves as a bridge.

The discovery of natural selection, by Darwin and Alfred Russel Wallace, must itself be counted as an extraordinary philosophical advance. The principle remained unknown throughout the more than 2,000-year history of philosophy ranging from the Greeks to Hume, Kant and the Victorian era. The concept of natural selection had remarkable power for explaining directional and adaptive changes. Its nature is simplicity itself. It is not a force like the forces described in the laws of physics; its mechanism is simply the elimination of inferior individuals. This process of nonrandom elimination impelled Darwin's contemporary, philosopher Herbert Spencer, to describe evolution with the now familiar term "survival of the fittest." (This description was long ridiculed as circular reasoning: "Who are the fittest? Those who survive." In reality, a careful analysis can usually determine why certain individuals fail to thrive in a given set of conditions.)

The truly outstanding achievement of the principle of natural selection is that it makes unnecessary the invocation of "final causes"—that is, any teleological forces leading to a particular end. In fact, nothing is predetermined. Furthermore, the objective of selection even may change from one generation to the next, as environmental circumstances vary.

A diverse population is a necessity for the proper working of natural selection. (Darwin's success meant that typologists, for whom all members of a class are essentially identical, were left with an untenable viewpoint.) Because of the importance of variation, natural selection should be considered a two-step process: the production of abundant variation is followed by the elimination of inferior individuals. This latter step is directional. By adopting natural selection, Darwin settled the several-thousand-year-old argument among philosophers over chance or necessity. Change on the earth is the result of both, the first step being dominated by randomness, the second by necessity.

Darwin was a holist: for him the object, or target, of selection was primarily the individual as a whole. The geneticists, almost from 1900 on, in a rather reductionist spirit preferred to consider the gene the target of evolu-

tion. In the past 25 years, however, they have largely returned to the Darwinian view that the individual is the principal target.

For 80 years after 1859, bitter controversy raged as to which of four competing evolutionary theories was valid. "Transmutation" was the establishment of a new species or new type through a single mutation, or saltation. "Orthogenesis" held that intrinsic teleological tendencies led to transformation. Lamarckian evolution relied on the inheritance of acquired characteristics. And now there was Darwin's variational evolution, through natural selection. Darwin's theory clearly emerged as the victor during the evolutionary synthesis of the 1940s, when the new discoveries in genetics were married with taxonomic observations concerning systematics, the classification of organisms by their relationships. Darwinism is now almost unanimously accepted by knowledgeable evolutionists. In addition, it has become the basic component of the new philosophy of biology.

A most important principle of the new biological philosophy, undiscovered for almost a century after the publication of *On the Origin of Species*, is the dual nature of biological processes. These activities are governed both by the universal laws of physics and chemistry and by a genetic program, itself the result of natural selection, which has molded the genotype for millions of generations. The causal factor of the possession of a genetic program is unique to living organisms, and it is totally absent in the inanimate world. Because of the backward state of molecular and genetic knowledge in his time, Darwin was unaware of this vital factor.

Another aspect of the new philosophy of biology concerns the role of laws. Laws give way to concepts in Darwinism. In the physical sciences, as a rule, theories are based on laws; for example, the laws of motion led to the theory of gravitation. In evolutionary biology, however, theories are largely based on concepts such as competition, female choice, selection, succession and dominance. These biological concepts, and the theories based on them, cannot be reduced to the laws and theories of the physical sciences. Darwin himself never stated this idea plainly. My assertion of Darwin's importance to modern thought is the result of an analysis of Darwinian theory over the past century. During this period, a pronounced change in the methodology of biology took place. This transformation was not caused exclusively by Darwin, but it was greatly strengthened by developments in evolutionary biology. Observation, comparison and classification, as well as the testing of competing historical narratives, became the methods of evolutionary biology, outweighing experimentation.

I do not claim that Darwin was single-handedly responsible for all the intellectual developments in this period. Much of it, like the refutation of French mathematician and physicist Pierre-Simon Laplace's determinism, was "in the air." But Darwin in most cases either had priority or promoted the new views most vigorously.

The basic principles of Darwin stood in total conflict with prevailing ideas.

The Darwinian Zeitgeist

A 21st-century person looks at the world quite differently than a citizen of the Victorian era did. This shift had multiple sources, particularly the incredible advances in technology. But what is not at all appreciated is the great extent to which this shift in thinking indeed resulted from Darwin's ideas.

Remember that in 1850 virtually all leading scientists and philosophers were Christian men. The world they inhabited had been created by God, and as the natural theologians claimed, He had instituted wise laws that brought about the perfect adaptation of all organisms to one another and to their environment. At the same time, the architects of the scientific revolution had constructed a worldview based on physicalism (a reduction to spatiotemporal things or events or their properties), teleology, determinism and other basic principles. Such was the thinking of Western man prior to the 1859 publication of *On the Origin of Species*. The basic principles proposed by Darwin would stand in total conflict with these prevailing ideas.

First, Darwinism rejects all supernatural phenomena and causations. The theory of evolution by natural selection explains the adaptedness and diversity of the world solely materialistically. It no longer requires God as creator or designer (although one is certainly still free to believe in God even if one accepts evolution). Darwin pointed out that creation, as described in the Bible and the origin accounts of other cultures, was contradicted by almost any aspect of the natural world. Every aspect of the "wonderful design" so admired by the natural theologians could be explained by natural selection. (A closer look also reveals that design is often not so wonderful—see "Evolution and the Origins of Disease," by Randolph M. Nesse and George C. Williams; Scientific American, November 1998.) Eliminating God from science made room for strictly scientific explanations of all natural phenomena; it gave rise to positivism; it produced a powerful intellectual and spiritual revolution, the effects of which have lasted to this day.

Second, Darwinism refutes typology. From the time of the Pythagoreans and Plato, the general concept of the diversity of the world emphasized its invariance and stability. This viewpoint is called typology, or essentialism. The seeming variety, it was said, consisted of a limited number of natural kinds (essences or types), each one forming a class. The members of each class were thought to be identical, constant, and sharply separated from the members of other essences.

Variation, in contrast, is nonessential and accidental. A triangle illustrates essentialism: all triangles have the same

fundamental characteristics and are sharply delimited against quadrangles or any other geometric figures. An intermediate between a triangle and a quadrangle is inconceivable. Typological thinking, therefore, is unable to accommodate variation and gives rise to a misleading conception of human races. For the typologist, Caucasians, Africans, Asians or Inuits are types that conspicuously differ from other human ethnic groups. This mode of thinking leads to racism. (Although the ignorant misapplication of evolutionary theory known as "social Darwinism" often gets blamed for justifications of racism, adherence to the disproved essentialism preceding Darwin in fact can lead to a racist viewpoint.)

The common ancestry of humans and apes has never again been seriously questioned.

Darwin completely rejected typological thinking and introduced instead the entirely different concept now called population thinking. All groupings of living organisms, including humanity, are populations that consist of uniquely different individuals. No two of the six billion humans are the same. Populations vary not by their essences but only by mean statistical differences. By rejecting the constancy of populations, Darwin helped to introduce history into scientific thinking and to promote a distinctly new approach to explanatory interpretation in science.

Third, Darwin's theory of natural selection made any invocation of teleology unnecessary. From the Greeks onward, there existed a universal belief in the existence of a teleological force in the world that led to ever greater perfection. This "final cause" was one of the causes specified by Aristotle. After Kant, in the *Critique of Judgment*, had unsuccessfully attempted to describe biological phenomena with the help of a physicalist Newtonian explanation, he then invoked teleological forces. Even after 1859, teleological explanations (orthogenesis) continued to be quite popular in evolutionary biology. The acceptance of the *Scala Naturae* and the explanations of natural theology were other manifestations of the popularity of teleology. Darwinism swept such considerations away.

(The designation "teleological" actually applied to various different phenomena. Many seemingly end-directed processes in inorganic nature are the simple consequence of natural laws—a stone falls or a heated piece of metal cools because of laws of physics, not some end-directed process. Processes in living organisms owe their apparent goal-directedness to the operation of an inborn genetic or acquired program. Adapted systems, such as the heart or kidneys, may engage in activities that can be considered goal seeking, but the systems themselves were acquired during evolution and are continuously fine-tuned by natural selection. Finally, there was a belief in cosmic teleology, with a purpose and predetermined goal ascribed to everything in nature. Modern science, however, is unable to substantiate the existence of any such cosmic teleology.)

Fourth, Darwin does away with determinism. Laplace notoriously boasted that a complete knowledge of the current world and all its processes would enable him to predict the future to infinity. Darwin, by comparison, accepted the universality of randomness and chance throughout the process of natural selection. (Astronomer and philosopher John Herschel referred to natural selection contemptuously as "the law of the higgledy-piggledy.") That chance should play an important role in natural processes has been an unpalatable thought for many physicists. Einstein expressed this distaste in his statement, "God does not play dice." Of course, as previously mentioned, only the first step in natural selection, the production of variation, is a matter of chance. The character of the second step, the actual selection, is to be directional.

Despite the initial resistance by physicists and philosophers, the role of contingency and chance in natural processes is now almost universally acknowledged. Many biologists and philosophers deny the existence of universal laws in biology and suggest that all regularities be stated in probabilistic terms, as nearly all so-called biological laws have exceptions. Philosopher of science Karl Popper's famous test of falsification therefore cannot be applied in these cases.

Fifth, Darwin developed a new view of humanity and, in turn, a new anthropocentrism. Of all of Darwin's proposals, the one his contemporaries found most difficult to accept was that the theory of common descent applied to Man. For theologians and philosophers alike, Man was a creature above and apart from other living beings. Aristotle, Descartes and Kant agreed on this sentiment, no matter how else their thinking diverged. But biologists Thomas Huxley and Ernst Haeckel revealed through rigorous comparative anatomical study that humans and living apes clearly had common ancestry, an assessment that has never again been seriously questioned in science. The application of the theory of common descent to Man deprived man of his former unique position.

Ironically, though, these events did not lead to an end to anthropocentrism. The study of man showed that, in spite of his descent, he is indeed unique among all organisms. Human intelligence is unmatched by that of any other creature. Humans are the only animals with true language, including grammar and syntax. Only humanity, as Darwin emphasized, has developed genuine ethical systems. In addition, through high intelligence, language and long parental care, humans are the only creatures to have created a rich culture. And by these means, humanity has attained, for better or worse, an unprecedented dominance over the entire globe.

Sixth, Darwin provided a scientific foundation for ethics. The question is frequently raised—and usually rebuffed—as to whether evolution adequately explains healthy human ethics. Many wonder how, if selection rewards the individual only for behavior that enhances his own survival and reproductive success, such pure selfishness can lead to any sound ethics. The widespread thesis

of social Darwinism, promoted at the end of the 19th century by Spencer, was that evolutionary explanations were at odds with the development of ethics.

We now know, however, that in a social species not only the individual must be considered—an entire social group can be the target of selection. Darwin applied this reasoning to the human species in 1871 in *The Descent of Man*. The survival and prosperity of a social group depends to a large extent on the harmonious cooperation of the members of the group, and this behavior must be based on altruism. Such altruism, by furthering the survival and prosperity of the group, also indirectly benefits the fitness of the group's individuals. The result amounts to selection favoring altruistic behavior.

Kin selection and reciprocal helpfulness in particular will be greatly favored in a social group. Such selection for altruism has been demonstrated in recent years to be widespread among many other social animals. One can then perhaps encapsulate the relation between ethics and evolution by saying that a propensity for altruism and harmonious cooperation in social groups *is* favored by natural selection. The old thesis of social Darwinism—strict selfishness—was based on an incomplete understanding of animals, particularly social species.

The Influence of New Concepts

Let me now try to summarize my major findings. No educated person any longer questions the validity of the so-called theory of evolution, which we now know to be a simple fact. Likewise, most of Darwin's particular theses have been fully confirmed, such as that of common descent, the gradualism of evolution, and his explanatory theory of natural selection.

I hope I have successfully illustrated the wide reach of Darwin's ideas. Yes, he established a philosophy of biology by introducing the time factor, by demonstrating the importance of chance and contingency, and by showing that theories in evolutionary biology are based on concepts rather than laws. But furthermore—and this is perhaps Darwin's greatest contribution—he developed a set of new principles that influence the thinking of every person: the living world, through evolution, can be explained without recourse to supernaturalism; essentialism or typology is invalid, and we must adopt population thinking, in which all individuals are unique (vital for education and the refutation of racism); natural selection, applied to social groups, is indeed sufficient to account for the origin and maintenance of altruistic ethical systems; cosmic teleology, an intrinsic process leading life automatically to ever greater perfection, is fallacious, with all seemingly teleological phenomena explicable by purely material processes; and determinism is thus repudiated, which places our fate squarely in our own evolved hands.

To borrow Darwin's phrase, there is grandeur in this view of life. New modes of thinking have been, and are being, evolved. Almost every component in modern man's belief system is somehow affected by Darwinian principles. SA

This article is based on the September 23, 1999, lecture that Mayr delivered in Stockholm on receiving the Crafoord Prize from the Royal Swedish Academy of Science.

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ERNST MAYR is one of the towering figures in the history of evolutionary biology. Following his graduation from the University of Berlin in 1926, ornithological expeditions to New Guinea fueled his interest in theoretical evolutionary biology. Mayr emigrated to the U.S. in 1931 and in 1953 joined the faculty of Harvard University, where he is now Alexander Agassiz Professor of Zoology, Emeritus. His conception of rapid speciation of isolated populations formed the basis for the well-known neoevolutionary concept of punctuated equilibrium. The author of some of the 20th century's most influential volumes on evolution, Mayr is the recipient of numerous awards, including the National Medal of Science.

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