# EPILOGUE

Alfred North Whitehead remarked that the European philosophical tradition was but a series of footnotes to Plato.[1] A comparable but more far-reaching observation might be made about Charles Darwin: since the late nineteenth century, intellectual life not only in philosophy but in the sciences and in other areas of cultural significance has been decisively shaped by Darwin's accomplishment. Footnotes to the *Origin of Species* gather like ants to the careless picnic of modern life. Though we, the authors of this book, have major differences in our interpretations of Darwin's theoretical conceptions, we are in little doubt about their impact on the sciences, humanities, and culture more generally. In biology, his ideas have dominated and shaped its history through the last century and a half, and those ideas have recast the understanding of ourselves. In this epilogue, we would like to sketch the major features of that more recent history, noting a few of the fault lines that threaten even this, our small edifice of comity. Of course, substantial changes have occurred in evolutionary theory since Darwin's time, which, we believe, would have surprised—and gratified—him. Nonetheless, even those changes have their roots in his theory, so it would not mischaracterize the biology of the modern period to call it Darwinian, or more precisely, neo-Darwinian. This biology has come to situate human beings into their distinctive place in nature.

## HISTORY OF EVOLUTIONARY BIOLOGY SINCE THE *ORIGIN OF SPECIES*

In 1900, biologists recovered and then, for the next several decades, recast the Moravian monk Gregor Mendel's (1822–84) ideas about hereditary patterns of trait transmission and how to explain those patterns. Particularly at the hands of Hugo de Vries (1848–1935) at the University of Amsterdam and Thomas Hunt Morgan (1866–1945) and his students (Alfred Sturtevant, 1891–1970; Calvin Bridges, 1889–1938; and H. J. Muller, 1890–1967) at Columbia University, the new theory of "genetics" was articulated and developed.[2] Initially it was seen to be a rival to Darwinian approaches to evolution; at the time, the historian Erik Nordenskiöld (1872–1933) even declared Darwinism dead, killed by the real science of the genetics laboratory.[3] In the 1930s, however, biologists began to combine genetic conceptions with Darwinian theory, and a new paradigm gradually emerged, usually called the "synthetic theory" (in America) or the "neo-Darwinian theory" (in England). With the systematic application of mathematics to population structures, the synthetic theory underwent rapid development, especially with the formulation of a principle that specified when a population would be in equilibrium (no change) and how it would change in a predictable fashion under selection pressures. The Hardy-Weinberg principle, named after the British mathematician G. H. Hardy (1877–1947) and the German physician Wilhelm Weinberg (1862–1937), held a position in biology something akin to Newton's first law of motion. With these additions, neo-Darwinism became a theory of the changing genetic structure of populations of organisms. For some biologists, the force of selection has penetrated to the genes; others have held fast to the individual organism as the focus of selection, with genes being carried along by their vehicle, though ultimately responsible for species change through time.

In the early 1930s, the "population geneticists"—notably R. A. Fisher (1890–1962) and J. B. S. Haldane (1892–1964) in England, and Sewall Wright (1889–1988) in the United States—developed the formal theory, and rapidly thereafter a number of naturalists and experimental scientists put empirical flesh on the mathematical skeleton. In England E. B. Ford (1901–88) and his school of "ecological genetics" were important; in the United States, the Russian-born Theodosius Dobzhansky (1900–1975) and his associates—the systematist Ernst Mayr (1904–2005), the paleontologist G. G. Simpson (1902–84), and the botanist G. L. Stebbins (1906–2000)—all contributed to the new theory, if with some crucial differences among them.[4] By the hundredth anniversary of the *Origin* in 1959, the neo-Darwinian synthesis was in place. Or more precisely, rapidly falling into place, for this was also the decade of the double helix, when James Watson (1928–) and Francis Crick (1916–2004) discovered the helical structure of the DNA molecule and therewith provided the foundation for the fine structure of the gene.[5] It seems fair to say, however, that although molecular studies at first appeared threatening to evolutionary theory—a parallel to the beginning of the century when Mendelism posed a danger—before long the insights about the molecular structure of the gene opened new approaches and ways of answering earlier, perplexing questions, especially about the hereditary transmission of traits.

Heraclitus observed that everything flows, and this has been very much true of evolutionary studies. The past century has seen one new finding after another, one new theoretical model after another, one new triumph after another. Let us briefly survey four areas and indicate the kinds of development they have undergone: natural selection theory, paleontology, embryology, and human evolution.

## *Natural Selection*

From the last third of the nineteenth century through the first two decades of the twentieth century, Darwin's chief device of evolutionary change, natural selection, gradually pushed out its principal rival, Lamarckian inheritance of acquired characteristics. Alfred Russel Wallace (1823–1913) in England and August Weismann (1834–1914) in Germany rejected the Lamarckian alternative. Weismann's experiments, on five generations of mice, demonstrated that cutting the tails of mice in each ancestor generation did not cause any shortening of tails in their descendants.[6] These empirical experiments coupled with theories (like Weismann's) that maintained a separation between the germplasm (hereditary material passed from parents to offspring) and the somatoplasm (hereditary material responsible for development of the individual organism) finally extinguished Lamarckism by the mid part of the 1920s (with the exception of a few doctrinaire holdovers in Russia).[7] Some other devices, like genetic drift and structural constraints, complemented natural selection, which became the only major cause the synthetic theory would tolerate. Darwin would have been surprised at the elimination of the inheritance of acquired characteristics from the biologist's repertoire; and he would have been equally astonished at the idea that selection could maintain variation within populations rather than always driving groups to one form or another. The disease sickle-cell anemia is the paradigm case of the retention of variation. Untreated, it leads to an early and painful death. We now realize that, far from selection working to eliminate the gene that leads to this disease—as one might think from an untutored Darwinian perspective—selection is willing to pay the price of a certain proportion (about 4 percent) of disease sufferers who have the gene in the homozygous condition (i.e., they get a double dose of the gene). Evolution pays the price, as it were, because in the heterozygous condition (i.e., when paired with a normal gene), the sickle-cell gene can also confer immunity to malaria, a killer disease in the parts of Africa where the sickle-cell gene was originally found. Selection "balances" the cost of a percentage of very unfit organisms against the benefit of having many more fit organisms.[8]

In the fifty years since the centenary of the *Origin*, increasing attention has been turned to the problem of the levels of selection. In Darwin's view, selection usually wrought its effects on the individual, though in the view of some it can also work at the group level—the reader will have seen that Richards and Ruse fail to agree about this latter issue. In the case of both the individual and the group, selection would have been assumed to work on the whole phenotype (as we would say). But in the 1960s and 1970s, population genetics refocused attention to the gene, arguing that selection principally operated at this most fundamental level. Even complex traits in social organisms came to be understood as resulting from genetic selection. William Hamilton (1936–2000), for instance, formalized a model of "kin selection," demonstrating that an altruistic trait could increase in a population if the trait inclined the bearer to help relatives who also carried the gene for the trait. This was obviously in the spirit of Darwin's family selection. Hamilton, though, was able to take matters to a higher level of sophistication both because of his knowledge of genes and through the application of a shrewd mathematical analysis: roughly, that a trait would be selected if its cost to the carrier were not greater than the benefit to the carrier's relatives in proportion to their degree of relatedness.[9] Or as J. B. S. Haldane more convivially put it when asked if he would jump into a river to save a drowning child: he would gladly risk his life for two brothers or eight cousins (since on average they would represent his own genetic endowment).[10] The American Robert Trivers formulated a complementary model of "reciprocal altruism" and provided various kinds of empirical support for the model.[11] This idea, also grasped in essence by Darwin, has selection promoting quasi-altruistic behavior in organisms because they implicitly expect aid in return. Darwin, though, regarded such expectation as a "low" motive.

Models constructed by population geneticists and social theorists like Hamilton and Trivers, along with the burgeoning amount of empirical evidence that had accumulated by the third quarter of the century, was gathered together in 1975 in one magnificent overview—*Sociobiology: The New Synthesis*—by the American ant-specialist Edward O. Wilson (1929–). The year after, 1976, the English biologist Richard Dawkins (1941–) wrote a famous popular account, *The Selfish Gene*, that summarized a good deal of the individual-selectionist view.[12]

Wilson's work was controversial. It was felt, perhaps with some good reason, that he was insensitive to issues of race and gender. He was also charged with being a rather simpleminded reductionist—something he certainly was not. Criticisms notwithstanding, new studies of the evolution of social structure surged. In the four subsequent decades, a large number of research projects advanced, showing the virtues of an approach to organic nature through natural selection as the principal force shaping animal communities. Societies of dung flies, guppies, lions, naked mole rats, chimpanzees, and many more species were analyzed in this way with incredibly rich results. The principal assumption of this research was that selection operated on individuals or individual-like entities—for example, kin groups. The emphasis on the individual came as a result of the critical analyses, undertaken by George Williams (1926–2010) in the late 1960s, of the then-current models of group selection. Williams discriminated several telling logical and empirical problems in the work of such group selectionists as V. C. Wynn Edwards (1906–97).[13] In the very recent period, however, new models of group selection have been proposed and new experiments conducted—by Michael Wade, David Sloan Wilson, and even by E. O. Wilson—that purport to provide support for the reality of group selection.[14]

## *Paleontology*

Darwin knew that he needed considerable spans of time for species change to occur, but neither he nor his supporters nor his critics knew exactly how much time was needed. Paradoxically, the physical sciences have come to his aid—paradoxical because in the early years after the *Origin* the physicists (ignorant as they were of the warming effects of radioactive decay) were precisely those scientists who contended that there was nothing like the needed time for so slow a process as evolution by natural selection. They drew their evidence from the assumed rate of salt deposition into the sea, heat loss from the earth, and suppositions about the composition of the sun. William Thomson, Lord Kelvin (1824–1907), estimated that the earth would have cooled from its molten state to be able to sustain life only between 98 and 200 million years ago. Though Darwin felt the objection of insufficient time when pronounced by the physicists, he was more wily than one might suspect. In subsequent editions of the *Origin*, he kept ratcheting down the time needed for evolutionary processes, playing on our inability to imagine how long, say, a million years really was and how many generations would turn over in that time.[15]

Now of course we know that the universe is about 13.8 billion years old, that our planet is around 4.5 billion years old, and that life seems to have started almost as soon as the globe got cool enough to bear it, maybe 3.5 billion years ago or even earlier. Today, although significant advances have been made in our understanding of the subject, we are still very far from having a complete story of origins.

Tremendous progress has been made, however, in reconstructing phylogenies that chart the history of life through long periods of time. Expectedly, some areas of the fossil record are better known than others. The evidence of the first 3 billion years of life's history is miniscule compared to the evidence for the last half-billion years. But the story is consistent. We start with primitive forms and work up through the ages to more complex forms. Particularly significant was the Cambrian explosion, more than 500 million years ago, when many of the phyla we find today first appeared in the record. Even more significant is the fact that we do not find anomalies. As Haldane is reputed to have said, there are no rabbits in the pre-Cambrian.

Though Darwin started his professional career as a geologist with a deep interest in paleontology, the *Origin* reveals only a little of his specific phylogenetic concerns—beyond, that is, the descent of fancy pigeons (chapter 1). Of course, in his four volumes on barnacles (1851–54), he traces various species back to their origins in a primitive crustacean rather than in some early mollusk, the class in which Georges Cuvier (1769–1832) placed them. Like his friend Ernst Haeckel (1834–1919), Darwin found the principle of recapitulation to be particularly helpful in establishing the phylogeny of barnacles.[16] In the *Descent of Man*, he did have some speculations about human phylogeny and origins. He presciently supposed that early man developed in Africa and spread to various regions of the world; and he regarded current aboriginal groups as representative of the European's ancestors. Darwin remarked in the *Origin of Species* that the fossil record of phylogenetic development looked like a book with most of its pages torn out, leaving only scattered sentences. Today, many of those pages and sentences have been found and reinserted. The book of life still contains mysteries, but of a more mundane variety.

The past half century has seen a sea change in paleontology with the growth of a whole new subdiscipline of paleobiology, where fossils are treated with all the consideration usually reserved for living organisms.[17] The Hardy-Weinberg law applies as much to trilobites as it does to West Africans. Particularly important is the use by paleontologists (or paleobiologists) of a form of what is known as "reverse engineering," a version of optimization theory. This is as standard a Darwinian way of doing things as it is possible for anything to be. One sits down with a tricky facet of the organic world and tries to puzzle out its meaning from an adaptive perspective, asking how would one design such a structure given a particular problem and the tools and materials to do so. A nice example of the technique occurred when, in 1862, Darwin received an orchid, *Angraecum sesquipedale*, from Madagascar; it had a nectary (the tube at the end of which sweet syrup would pool) of a foot long. He predicted that there had to be a moth on the island with a comparably long proboscis; the creature was discovered in 1903, some forty years after Darwin's prediction.[18]

Darwin used the strategy of reverse engineering repeatedly not only in the particular case of the Madagascar orchid, but as well in the little book on orchids that he penned at the time.[19] The strategy is also fundamental to today's paleontologists, faced as they are with the strange features of brutes from the past. Why does that magnificent dinosaur, the stegosaurus, have weird pointed plates all the way down its back? Various hypotheses have been proposed. Perhaps they arose through sexual selection. Not likely, because both males and females have them. Maybe they were needed for defense or attack. Not likely, because the plates were not anchored to the backbone. Could be that they were used for temperature control, heating the cold-blooded animal in the morning sun and cooling it at midday in the breezes. Much more likely, especially given that the plates seem just like the plates used for heat transfer in air conditioners. There is confirming evidence from the ways in which blood could have been transferred to the plates; although this has led to a rival or supplementary explanation that a large flow of blood could lead to a kind of blushing and hence to a magnificent threat display.

While one function (e.g., heat control) might have been an originating cause, this would not preclude multiple functions for the plates.[20] Asking the adaptive question leads to quite interesting possibilities in the understanding of evolution.

### *Development*

Darwin took development very seriously, especially the relationship between the embryo and the adult organism, a relationship that for him became important evidence of the general theory of descent. In the *Origin*, he utilized the principle of recapitulation (that the embryo goes through the same morphological stages as the phylum had in its evolutionary descent): “Embryology rises greatly in interest, when we thus look at the embryo as a picture, more or less obscured, of the common parent-form of each great class of animals.”[21] He became more than a little vexed that critics failed to notice the role of embryology and individual development in his theory. During the period of the synthesis, embryology and development remained of small concern. Most population biologists started with the gene and then jumped straight to the finished organism—from the genotype to the phenotype. If one dips into the popular account given in the *Selfish Gene*, there is much on the relationship between genes (tokens or markers for selection) and the organisms (the frontline troops in the struggle for existence) and not a lot in between. To use a familiar metaphor, organisms were black boxes.

How things have changed! Starting around 1980 or earlier, in the field of evolutionary development (“evo devo” for short), molecular biologists have been tracing the path from the genes, from the DNA molecule, up to the finished organism; and along the way they have come up with some truly staggering discoveries.[22] Perhaps most remarkable is the news that organisms are built along the Lego principle. Put the building blocks together one way and you get the Eiffel Tower; put them another way and you can ride in a Ferris wheel. So in the organic world. Organisms are not built anew from scratch every time. The same molecular components are used, though in different ways, for making a mouse and for making an elephant. Amazing! We might have expected some similarities, let us say between humans and orangutans. But between *Homo* and *Drosophila*?

Obviously all of this is way beyond the expectations of Charles Darwin and his contemporaries. In the 1960s, the human genome was estimated at about 100,000 genes, with simpler organisms assumed to have considerably fewer. Most recently the estimate for the number of human genes has been radically reduced to about 21,000, while the water flea clocks in at 31,000.[23] Obviously sheer numbers of genes do not determine phenotypic complexity; regulation of genes by other genes functions where sheer numbers fail. But are these findings threatening in any sense? Absolutely not! Biological science, like other sciences, continues to advance with better models and better data. The boy who loved chemistry, the young Charles Darwin, would very likely be quite fascinated by these developments in molecular genetics.

## *Humans*

Again, huge advances have been made in the biology of human beings since Darwin. The Neanderthals were known before the *Origin*, though the great German anthropologist Rudolf Virchow (1821–1902) thought they were the remains of brutish Russians who had chased Napoleon back into France.[24] The first proto-human recognized as such was discovered in the early 1890s, Java Man, found by Haeckel's protégé Eugene Dubois (1858–1940).[25] Then, in the twentieth century starting with the Taung baby (an australopithecine or southern ape), discovered in South Africa by Raymond Dart (1893–1988), the fossils gushed forth. Great credit goes to the indefatigable Leakey family working in East Africa, although the find of the century was surely "Lucy," a little hominin just over three feet tall, with a chimpanzee-sized brain (about 400 cubic centimeters as opposed to our 1,250 cubic centimeters), walking on her hind legs, and more than 3 million years old. Molecular biologists who showed that estimates of a 10-million-year separation of apes from the human line were initially far too conservative. We split about 5 million years ago and, whatever the appearances, it seems that we humans are more closely related to chimpanzees than the chimpanzees are to the gorillas.[26] Molecules again have recently been in the news as researchers have been able to collect ancient DNA and have answered that intriguing question: Did Neanderthals and *Homo sapiens* engage in any trysts? The answer apparently is yes, since we carry some few Neanderthal genes, the results of occasional interbreeding till the Neanderthal line ran out, about 40,000 years ago.[27] Old-fashioned fossil hunting has turned up one of the most remarkable of all discoveries, the little hominin, *Homo floresiensis*, a creature dubbed "the hobbit," from Indonesia. *H. floresiensis* seems to have lived as recently as 12,000 years ago, and perhaps descended as an isolated group from *Homo erectus*.[28]

All of this would be new to Darwin, although nothing of great conceptual surprise or worry. Darwin, like all of his contemporaries, assumed that there was a progressive path to humans, an assumption now challenged. But the rise of human brainpower, if unexpected, is not totally inexplicable, as our ancestors used their new adaptation to hunt and forage and probably to fight fellow species members. What about those brains? It is clear that Darwin had little time for a blank-slate theory of intelligence. He thought that the ways in which we reason and act, particularly act morally, were (to use a modern metaphor) part of the brain's software. This is the beginning assumption of a whole class of modern-day Darwinians, the "evolutionary psychologists." They argue that our reasoning and our moral sense are both part of our genetic heritage. They would agree with Darwin that such things as basic reasoning—logic, mathematics, and above all language abilities—are part of our innate legacy as given to us by evolution through natural selection. Where they would go beyond Darwin, perhaps, is in arguing that some of the quirks of our reasoning are likewise explained by selection, though against a much earlier environment, one rather different from ours.[29]

Theories of moral evolution have been the subject of much scrutiny in recent years. Experimental studies of apes and monkeys, for instance, have shown that these creatures engage in what appears to be protomoral behavior (e.g., consolation for injuries suffered) or even apply moral norms (e.g., negative expressions when elemental standards of justice are violated).[30] Survey studies of human beings—across nationalities, culture, religion, and education—indicate common, deep-seated intuitions about morally appropriate behavior. Paradigmatic are the trolley problems. When subjects are presented with these problems their resolutions indicate a general consensus about circumstances under which one feels a moral obligation to save five people at the expense of one and about other circumstances in which such a trade-off feels morally wrong.[31] Darwin, of course, pioneered the proposal that selection has instilled in human beings deep-seated instincts about morally appropriate behavior.

## HUMAN CONSCIOUSNESS

Theodosius Dobzhansky remarked that "nothing in biology makes sense except in the light of evolution," and the evolution he had in mind was Darwinian.[32] Beyond the confines of empirical biology, however, does Darwinism have implications for the traditionally metaphysical questions concerning human consciousness? We believe it does, though such implications cannot be completely decisive in answering these questions.

As every moderately literate individual knows, a large number of positions have been taken on the relationship between human mind and human brain. We don't propose to discuss the multitude of these positions, which multiply like inflating universes. (C. D. Broad in 1925 enumerated some seventeen different mind-body theories; and others have emerged since.)[33] We will, rather, consider the most prominent ones, with a word or two about their varieties. They fall under four somewhat overlapping categories: dualism, materialism, monism, and emergentism. In what follows, we will assess these positions in relation to evolutionary theory.

Cartesian dualism contends that mind and brain are separate entities. Descartes (1596–1650) believed that the properties of each were radically different, and so had to be located in separate kinds of substance: a mental, thinking entity and a material, extended entity. Descartes's view had its roots in Plato and subsequent medieval philosophers. Many religious conceptions of human beings suppose some kind of dualism, since the doctrine holds the promise of life after death. The great Renaissance anatomist Vesalius (1514–64) expressed the common view, which he inscribed in his classic depiction of the human body: "Vivitur ingenio, caetera mortis erunt" ("Mind lives, all else is mortal").[34] Substance dualism is an all or nothing kind of thing. Even Erik Wasmann (1859–1931), a Jesuit evolutionist of the late nineteenth and early twentieth centuries, whose views became canonical among Catholic theologians and philosophers, required that at some moment during the evolution of man's body, God infused the soul, which carried the human mind.[35] Darwinism precludes the endorsement of such miracles. Mind, in the Darwinian view, is a historical accomplishment, gradually becoming more complex in the hominid line, but with mental and psychological traits found at various levels in the collateral branches within the animal kingdom.

Materialism comes in several varieties. The most radical position is that of Daniel Dennett, who argues that consciousness, human mind, simply does not exist. All that exists is the human brain, which consists ultimately of particulate matter. By this strategy, Dennett tries to avoid what has become known as the "hard problem" in the philosophy of mind, namely, the relationship between brain and a unified consciousness, a self. He virtually reverses the Vesalian epigram. In order to make his argument stick, he has to contend that qualia—the red and green, the rough and smooth, the loud and soft, the hot and the cold of our experience (those purported objects of consciousness)—do not really exist.[36] Since not all of our brain activity produces apparent phenomenal awareness, Dennett must suppose there is no real distinction between brain activity that produces apparent consciousness and that which does not. After all, in his view, unified consciousness does not exit. But virtually all of neuroscience makes this fundamental distinction between conscious experience and brain activity; indeed, fMRI investigations of the neural substrate of consciousness suppose the existence of consciousness to guide and verify features of neural activity. Dennett's arguments are as ingenious as they are unconvincing.

Another version of materialism maintains that mind is simply the behavior or function of the brain, the brain's activity. The distinction between brain states that function without consciousness and those that produce consciousness must lie in different kinds of activity. But either mind activity is like ordinary neural activity that doesn't have conscious accompaniment—then it's essentially a version of the radical type of materialism—or that particular activity of the brain is different. Yet the only difference could be that it produces phenomenal awareness. In regard to the first alternative, one could imagine a race of apparent human beings whose brains work as ours do but without phenomenal experience—the zombies that populate contemporary films and TV. But such creatures would be distinctively different from us—the difference being consciousness. So materialism must recognize a particular kind of neural activity that gives rise to consciousness; and that activity is identified precisely by its production of consciousness. But then consciousness must be something more than the ordinary activity of the brain. This leads to the position of epiphenomenalism.

So human brains (and brains of higher animals) do produce phenomenal conscious states with their blazing array of qualia, and these cannot be simply identical with ordinary brain states. The epiphenomenalist holds that states of consciousness produced by human brains are simply inert; they are like, say, the redness of blood—a property that has no function but is only, as it were, carried along by the hemoglobin molecule, which does have a function. So this version of materialism maintains that consciousness is a property produced by the human brain but one that has no causal function. Thomas Henry Huxley endorsed this kind of mind-brain theory. Huxley argued that brain activity had two different kinds of effect: it caused physiological and behavioral actions, and it also caused consciousness states. But the conscious states, in their turn, were inefficacious; they did no work.[37] William James (1842–1910) produced a telling Darwinian argument against this version of "steam-whistle" epiphenomenalism—so called because consciousness is supposed to have no more effect on actions than the whistle on a locomotive—and he was followed by the philosopher Karl Popper (1902–94) and the Nobel laureate and neurophysiologist John Eccles (1903–97), both of whom subscribed to James's argument.[38] If consciousness slowly evolved from its first glimmers in early animals through proto-humans to modern man, like all properties it must have evolved under the aegis of natural selection. But then if selected, it must have a use; otherwise selection would have eliminated such a costly but unproductive trait, leaving only zombies in both the animal and human lines. If consciousness has a use, then it must do work beyond what the naked brain performs.[39]

The counterargument of a convinced epiphenomenalist might be that consciousness is simply a necessary concomitant of brains (like the red of the hemoglobin molecule). But the recalcitrant epiphenomenalist must recognize that consciousness, along with brains, has become ever more complex over evolutionary time, that the features of consciousness show developmental integration (of perceptions, memory, deliberation, feelings, etc.). Yet there is no reason to suppose that the integration of features of consciousness should match the integration of brain parts. If it were simply the case that a set of brain parts produced a concomitant set of conscious parts in the way hemoglobin produces the color red, there would be no reason to expect the conscious system to be anything but a hodgepodge, a Jackson Pollock of the mind. Brain may secrete thoughts as the liver secretes bile, as Darwin supposed, but the bile is real and does work, and analogously, so do thoughts.

At the end of the eighteenth century and through the early part of the twentieth, Spinoza's neutral monism gained a second wind. Goethe, Haeckel, Wallace, Spencer, Schelling, Mach, and Russell all endorsed a neutral monism of varying differences. For Baruch Spinoza (1632–77), mind and matter were properties of a single underlying substance; their coordination was assumed because of their deep connections. Herbert Spencer (1820–1903) supposed that each bit of matter came with a bit of mind as its concomitant; so there were as many substances and mini-minds as there were atoms. James and Bertrand Russell (1872–1970) contended that experience (or sensation) provided the neutral stuff, out of which we construct mind or matter: the red of the ribbon in our experience could be construed now as a feature of the physical world, now as a perception of the mind.[40] Many problems attend the various types of neutral monism that we've briefly mentioned, but two in particular stand out. In the case of Spencer and Wallace's version, William James objected that this was essentially a mind-dust theory: the little bits of consciousness, even if hovering around a brain, would have no central unity, no self to integrate and coordinate them.[41] This was precisely James's own problem, and Russell's as well. James's version of neutral monism held: "That entity [consciousness] is fictitious, while thoughts in the concrete are fully real. But thoughts in the concrete are made of the same stuff as things are."[42] Yet, what is the nature of that entity or mind doing the constructing of neutral experience, constructing this red as a mental perception at one time, a physical property at another? Moreover, one could ask whether objects exist in the universe that have never been experienced or sensed. Most sciences, especially evolutionary biology and physics, assume the existence of kinds of objects that have passed through no one's stream of thought. What justifies the assumption, perfectly ubiquitous, that such objects nonetheless exist and wait to be discovered?

Emergentism is the last view we would like to consider, and the one most comfortable with Darwinian theory. Emergentism holds that consciousness has gradually arisen as the nervous system has become ever more complex during the evolutionary history of organisms. This means that while humans possess the highest form of consciousness and rational capacity, other animals are not completely bereft of mind. This doesn't mean that if evolutionary theory in general is true, that mind must be its gradually evolved product, but it certainly makes emergentism more likely. Neo-Darwinians claim to be able to explain salient biological traits, and if mind is a biological trait—an emergent property of brain—then it should be explicable in terms of neo-Darwinian theory. If the rise of mind cannot be explained by evolutionary biology, then that might well cause us to hesitate about endorsing Darwinian theory. Thomas Nagel, a distinguished philosopher of mind, has recently argued that mind cannot be explained by evolutionary theory and thus evolutionary theory, as it stands, is radically incomplete. Something is missing. But that is to say, in Nagel's tendentious interpretation, evolutionary theory "is almost certainly false."[43]

Nagel has based his objections fundamentally on what he takes as the inability of evolutionary theory to solve the hard problem in the philosophy of mind, namely, explaining the features of consciousness using only the resources of evolutionary naturalism. We will enumerate several of the arguments he makes along the path to his most basic objection. His first salient argument is that an evolutionary construction of mind makes human reason unreliable: "Evolutionary naturalism provides an account of our capacities that undermines their reliability and in doing so undermines itself."[44] If our mental faculties have evolved to deal with very practical problems of life, they "do not warrant our confidence in the construction of theoretical [i.e., scientific] accounts of the world as a whole." This objection, of course, supposes distinctly different kinds of human mental capacities: those directed toward the everyday beliefs about the world and those directed to the establishment of scientific beliefs. But there is no justification for this distinction. The whole history of science testifies to the gradual application of common reasoning ability, exercised in the business of life, in the construction of scientific conceptions. Part of the repertoire of our cognitive dealings with the immediate world are various mental instruments for correcting initially faulty impressions: we certify that the stick in the water, though it looks bent, is really straight by feeling it, pulling it out of the water, noticing that all such objects in water look bent from the same angle. Those of our ancestors who lacked these corrective mental instruments, these checks on immediate perception, fared poorly in the struggle for existence. Is the correction of more abstract, scientific beliefs, fundamentally different? Our cognitive efforts in science, as the history of science makes clear, have been unreliable until yesterday; the science of the previous generation has been superseded, as we presume this one will be as well.

Getting closer to the heart of the matter, Nagel objects to "Naturalism," the program that regards things in the world as "physical things" and subject to natural law.[45] He believes the naturalism that is endemic to modern evolutionary biology fails to explain consciousness, because consciousness is not a physical thing. Contemporary physics, however, is willing to consider the ultimate foundation of reality in vibrating mathematical strings and to postulate the existence of "dark matter" and "dark energy," which seem to have properties radically different from what used to be thought of as the standard constituents of matter. Many philosophers who try to seal hermetically the realm of consciousness from the realm of matter still harbor Newtonian notions about matter, regarding it as constituted by those hard, glassy impenetrable particles that do seem so very different from the elements of consciousness. But contemporary naturalism, given the scope of modern science, seems ready to encompass any phenomena that can be comprehended and studied by human reason. The laws (deterministic or statistical) that now exist in the sciences presumably include the laws of population genetics, laws of learning in psychology, and sociological generalizations about small group phenomena. Few would deny that in psychology, reliable laws of conscious perception have been discovered—for example, color constancy—or that laws of cognitive development have been instrumental in understanding the behavior, say, of young children. Aren't these examples of an ingression of naturalism already into the domain of consciousness? The future development of the biological understanding of conscious phenomena appears wide open. What would be precluded under this more contemporary conception of naturalism would be supernatural entities whose behavior would in principle be inaccessible to human reason. Just as physics and biology endorse the emergence of new properties in the universe over evolutionary time spans, so there should be no a priori exclusion of the emergence of mind, as a new property of the universe.[46]

Another strategic way Nagel attempts to undermine evolutionary theory is by maintaining that its explanations are radically incomplete:

> Selection for physical reproductive fitness may have resulted in the appearance of organisms that are in fact conscious, and that have the observable variety of different specific kinds of consciousness, but

> there is no physical explanation of why this is so—nor any other kind of explanation that we know of.[47]

Nagel offers several variations on this theme of the insufficiency of evolutionary accounts: if mind has evolved through natural selection, how does this occur? More generally, exactly why does this kind of brain bring with it this kind of conscious mind?[48] Of course, we have some clues to the answers to these questions. Dogs and their evolutionary progenitors found advantage in detecting prey, which often would be hidden in high savanna grass, by an acute olfactory sense. So evolutionary theory does give an account of why we, who are principally visual creatures, have a less keen sense of smell compared to our dogs; and this is physically revealed in our proportionately smaller olfactory area of the brain. Evolutionary theory does, therefore, give an account of the complexity of certain brain areas associated with complexity of phenomenal experience: both resulted from selection pressures.

Nervous tissue, of the sort that constitute brains, arose through natural selection in the deep past; and it would appear that the first glimmers of consciousness have as well. But Nagel wants more: evolutionary theory "would have to offer some account of why the appearance of conscious organisms, and not merely of behaviorally complex organisms, was likely."[49] Admittedly, we are uncertain how the first glimmers of consciousness arose as an emergent phenomenon from nervous tissue. But then, we also don't quite understand how nerve cells evolved from other kinds of cells; yet that doesn't mean that natural selection as an explanation is deficient. By parity of reasoning the same holds for the gradual emergence of consciousness: a less than full explanation does not mean that evolutionary theory is false or mistaken—it may suggest, rather, that cell biology has not yet found its resting place.

Nagel is willing to push the demand for further explanation to the brink: How can one explain, he asks, the transition from non-life to life? He, following the intelligent designers, argues in Zeno-like fashion. If one can demonstrate, say, a transition between major animal groups, for example, between reptiles and mammals based on paleontological evidence, one can still ask: But wait, what about the intermediate stages? How were they made? And if a tentative answer is proffered, then one can pursue the ever smaller gap: What about the in-between step? This quest will never be satisfied. Why is grass green? Well, because of the light reflected off a surface that is absorbed by the retina at length of about 450 nanometers. But why is that length absorbed? Well, because of the kind of protein in the cones. But why does the protein absorb light in that range, and so on? At some point one must simply say that A causes B and no further explanation is possible, at least for the time being. But this is the situation with all of science, and so it is unreasonable to ask of evolutionary theory what is not asked of other sciences.

Natural selection theory, despite Nagel's appeal to Zeno's logic, does explain why consciousness exists: because it more effectively responds to environmental problems than automatisms can. Creatures low on the scale of consciousness must compensate for insufficient consciousness by hyper-reproduction, which is why the world is bulging with beetles; but as consciousness increases, organisms can be more flexible in their responses to the environment, and so reproduction declines.

The last redoubt of objections to which Nagel repairs is that of normative judgment both in our cognitive commerce with the world and with our moral commerce with other people. In the main body of this book, we have taken on the problem of human moral behavior, arriving, however, at different analyses of the role of evolution in determining moral capacities. But we are in agreement about the nature of consciousness and the Darwinian reply to Nagel's objections.

Nagel is willing to concede that sensation and perception of objects might yield to a natural selection account. But he thinks reason operates in a completely different way. In "ordinary perception, we are like mechanisms governed by a (roughly) truth-preserving algorithm." But in the case of reasoning, "something has happened that has gotten our minds into immediate contact with the rational order of the world order."[50] At this point, Nagel begins to light the candles, looking to peer beyond the natural world to discover in us an ability to come face to face with a different kind of realm than the natural. Need we go in that direction? Isn't there a more mundane explanation available? The algorithms of reasoning, patterns of cognitive activity that enshrine such imperatives as avoiding inconsistency, of recognizing the principle of "dictum de omni, dictum de nullo," and of proceeding systematically seem necessary requirements of social creatures that have begun to use language. And like the capacity for language, such principles would have been selected for over long periods of time. For a Darwinian, these principles are not the result of direct insight into the deep structure of reality, as Nagel seems to believe humans capable, but the result of pragmatically dealing with the world. The history of science does not indicate that researchers have utilized a preternatural insight into truth; rather that they have stumbled toward the refinement of cognitive instruments and have used them to comprehend a puzzling world.

What is missing from the Darwinian scenario, Nagel argues, is an appreciation of the teleological character of the evolution of life, of consciousness, and of reasoning ability. Intelligent designers also maintain that these processes of life, consciousness, and reasoning are teleologically structured; but they have a way of anchoring the notion of teleology: divine intention determines the effective aim and cause of the process. Nagel, being an atheist, rejects the intervention of a divine mind. But without an all-powerful intentionality fixing the end goals of life, of consciousness, and of reasoning capacity, what does it mean to suggest these processes are goal directed, teleologically structured?

A teleological causal analysis implies that a developmental process—for example, the gradual evolution of reasoning ability—has its further structure determined by the goal of the process—for example, human, scientific rationality—and that each of its stages is oriented toward that goal. If I decide to construct a model airplane, the plan I have in mind guides each of the steps that I take: the choice of the wood, the shape of the fuselage, the length of the wings, and so on. Without a determining mind behind organic processes, operating according to an idea, a plan, it's difficult to understand what kind of teleology Nagel is proposing. But there is one kind of teleology that he seems to dismiss—Darwinian teleology—which is perfectly adequate to the requirements he specifies.[51]

The general end of organisms, that which constitutes their goal, is reproductive success: that is the ultimate criterion or standard governing evolutionary processes. The environment and the previous state of the organism determine how that goal might be realized; they provide the structure of development leading to the goal. Consciousness and rationality might be used for many ends: solving mathematical problems, tracking a comet, or taking delight in a sunset. But these fundamental human capacities must have ultimately arisen for facilitating reproductive success. Darwinian natural selection was, after all, the full account that Nagel was searching for.

## RELIGION AND GOD

In his *Autobiography*, Darwin testified that at the time he finished the composition of the *Origin of Species*, he still believed that something like mind governed the universe.[52] The *Origin* itself demonstrates (at least for one of us) that Darwin's theistic belief helped structure his views about natural laws as secondary causes, with the divine mind as the primary cause. That belief gradually dissolved in succeeding years into an uncomfortable agnosticism, with Darwin declaring a few years before his death: "In my most extreme fluctuations I have never been an atheist in the sense of denying the existence of a God.—I think that generally (and more and more so as I grow older), but not always,—that an agnostic would be the most correct description of my state of mind."[53] In the *Descent of Man*, Darwin did, slyly, indicate what he thought to be the source of conventional religious attitudes. He reckoned that the aboriginal's belief in spirits and gods was comparable to the state of his little dog, who chased after a windblown parasol, assuming some imperceptible creature was moving it along. The "primitive" also attributed strange natural occurrences to the actions of unseen agents, and, like his dog, displayed a religious reverence for the invisible master. Darwin hastened to add, he was not touching on the question whether an omnipotent God actually exists, which "has been answered in the affirmative by the highest intellects that have ever lived."[54] Of course, Darwin was not only touching on the question, he was shaking its foundations.

Subsequent biologists, E. O. Wilson, for example, have argued that belief in God and the rituals of religion arose not only for reasons of the kind supposed by Darwin, but also for reasons of group solidarity. Religion might function to encourage both altruism and subordination to a group leader. There might even be a kind of cultural competition among religions, with one group's religion proving successful insofar as it promoted dominance over other groups.[55] Such functional evolutionary arguments, of course, are corrosive of traditional religion and dogmatic belief. Such acidic tendencies can be detected at work among the tribe of biologists.

In 1914, the psychologist James Leuba discovered that among scientists surveyed about 42 percent expressed a belief in a personal God (i.e., a being who would answer prayers); among elite scientists (those mentioned in *American Men of Science*), that figure fell to 35 percent; and for elite biologists, 17 percent.[56] In 1996, Larson and Witham repeated Leuba's survey, using more modern techniques of polling, and found that the level of belief in a personal God among scientists at large held pretty steady, about 39 percent. However, among elite scientists (members of the National Academy of Sciences) that figure fell to 7 percent. Among elite biologists, only 5.5 percent professed belief in a personal God.[57] It would appear that biologists of considerable acumen, like Darwin of later years, have regarded their science incompatible with a belief in a personal God.

Is there yet a way of squaring belief in a supernatural power with evolutionary theory? Certainly not with the beliefs of so-called scientific creationists. They have simply denied the great age of the earth and rejected the evolutionary transitions for which fossils and well-established dating techniques provide strong and comprehensive documentation. The best evidence shows, for example, that the cynodonts, a clade of therapsid reptiles that appeared about 275 million years ago, gave rise to the mammals about 50 million years later.[58] Our own line shows the same gradual transitions: from *Australopithecus afarensis* ("Lucy"), at about 3.5 million years ago, to *Homo habilis*, which had a brain size of about half ours and lived 2.5 million years ago, through the various lines of *Homo erectus*, and side lines of *Homo neanderthalensis*, to *Homo sapiens sapiens*, our species, which appeared about 43,000 years ago.[59] Not to forget, of course, the curious diminutive *Homo floresiensis*, likely a surviving branch of *Homo erectus* in Indonesia, which seems to have lived well into the time of modern man.[60] Quite clearly, these well-confirmed conclusions from recent evolutionary biology run counter to the beliefs of fundamentalists-creationists, who account for four in ten Americans. Thus a significant part of the American public are beyond the circle of science—and reason—at least on this topic.

In a Gallup poll of 2014, 42 percent of U.S. adults thought that species were created by God much as we now see them; 31 percent agreed that humans have evolved, but guided in the process by God; and 19 percent held that the neo-Darwinian process alone was sufficient for the evolution of human beings. The results might be contrasted with a similar poll in 1982, which yielded 44 percent, 38 percent, and 9 percent, respectively. In some thirty years, the percentage of Americans holding to the stark biblical story has changed very little, while the neo-Darwinian account seems to have moved those who had accepted theistic evolution into the category of evolution neat. It's hard to say what has caused this minor shift: perhaps more Americans receiving higher education, perhaps the failure of Creationism in the courts, perhaps the publicity given such prominent atheists as Richard Dawkins, Daniel Dennett, Samuel Harris, and Jerry Coyne—biologists and philosophers of biology all. Does this shift suggest the power of the evolutionary cum atheistic argument? And should we conclude that neo-Darwinian theory is strictly incompatible with religious belief?

The shelves of bookstores and the nudging suggestions of online providers are now replete with books arguing the stark opposition of Darwinian science to any religious belief. Daniel Dennett uncorked the current stream with *Darwin's Dangerous Idea* (1995). That stream, now at gentle flood, includes such books as Sam Harris's *The End of Faith: Religion, Terror, and the Future of Reason* (2005), Richard Dawkins's *The God Delusion* (2008), and Julien Musolino's *The Soul Fallacy: What Science Shows We Gain from Letting Go of Our*

*Soul Beliefs* (2015). Some authors, like Dennett, have again returned to the issue—in his *Breaking the Spell: Religion as a Natural Phenomenon* (2007)—and some, like Victor Stengler, seem obsessed: *God, the Failed Hypothesis: How Science Shows That God Does Not Exist* (2008); *God and the Folly of Faith: The Incompatibility of Science and Religion* (2012); *God and the Multiverse: Humanity's Expanding View of the Cosmos* (2014), and so on. The arguments in these books have a vintage ring to them. Most of these arguments can be found in simpler form in the pellucid essay by Bertrand Russell, "Why I Am Not a Christian" (1927), or earlier and with more colorful aplomb in Voltaire's *Dieu et les hommes* (1769). It's worthwhile examining the tenor of these arguments as they appear in the very recent book by the distinguished evolutionary biologist Jerry Coyne, in his *Faith vs. Fact: Why Science and Religion Are Incompatible* (2015).

Coyne directs his passionate attack against one particular strand in the science versus religion debate: arguments that try to preclude conflict by relegating religion strictly to the emotional and moral, while keeping science the preserve of the rational and empirical. Hence, in this lamented scenario, emotional states or moral claims about what ought to exist can lie down with any empirical claims about what does in fact exist. The most notable effort to launch this kind of accommodation is that of the late Stephen Jay Gould. Gould did not distill this division from the actual practice and pronouncements of theologians and scientists through the ages, but simply declared what religion and science should be. From such a subjunctive declaration, conflict is, of course, avoided:

> Science tries to document the factual character of the natural world to develop theories that coordinate and explain these facts. Religion, on the other hand, operates in the equally important, but utterly different realm of human purposes, meanings, and values—subjects that the factual domain of science might illuminate, but can never resolve.[61]

As Coyne is quick to point out, this stipulative definition of religion is violated by most of the earth's religions. Most religions make existential claims, at least by asserting God's existence; beyond that, many religions have proposed miraculous interventions in the world. Coyne doesn't mention it, but from the science side, values flow across any proposed boundary; that is, science itself is grounded in values. Thus, normative standards for acceptable knowledge-claims and for appropriate methods have formed the framework of science through the ages. Darwin himself often transgressed Gould's claim of separate and nonoverlapping magisteria when he invoked God as a primary cause in the *Origin* and later in the *Descent* undertook an evolutionary explanation of moral values. Darwin's efforts would have been arbitrarily precluded by Gould's irenic resolution to the science-religion struggle. Gould did not discover two nonoverlapping magisteria; he merely promulgated them as a normative resolution to the obvious conflict of science and religion. He made accommodation by fiat.

In dealing with some of the factual claims of prominent religions, such as the reality of Adam and Eve (whose existence is implicated in doctrines of original sin and the coming of Christ), Coyne handily arrays the findings of recent genetics. He also easily explodes the "genetical theories" of the Angel Moroni, who, according to Mormon doctrine, inscribed in the golden tablets that Native Americans originated in the Middle East. Insofar as these assertions of religious doctrine are taken straightforwardly as factual, science stands against them with compelling evidence. Against theistic evolution (of the kind Darwin seems to have entertained while writing the *Origin*), the countervailing considerations require more finesse.

Coyne himself at times slips into argument by fiat: "theistic evolution has been completely rejected by scientists."[62] What he must mean is that theistic evolution (i.e., evolution directed by divine power) has been rejected by a fair number of scientists, certainly not all. In his book, he cites several theistic evolutionists who have exemplary credentials as scientists.[63] A principal charge he brings against theistic evolution is the incompatibility with what we know of genetic change, particularly its contingency, which would argue against the theistic assumption of the inevitability of man. While this evidence does not tell against the sheer logical possibility of a divine power behind the scenes orchestrating the whole, it makes such assumptions look like an irrational stretch, an instance of faith overcoming likelihood. To make theistic evolution work, independent evidence for the existence of such a divine power would be required, some rational grounds that might provide a footing for faith. Coyne considers the kind of view advanced by Conway Morris and Kenneth Miller, both first-rate scientists and Christians.[64] These scientists argue that the phenomenon of convergent evolution suggests the existence in the deep past of an adaptive space favorable to greater intelligence, a space of the sort that would inevitably lead to human beings. But without other examples of convergent evolution of intelligence, the argument has no power: that humans have evolved logically implies only that the conditions of possibility were antecedent; thus the argument from adaptive space seems only to mean that since humans did evolve, they could have evolved. That hardly appears to supply the rational footing wanted.

Was human evolution contingent, as Coyne suggests, or fixed in advance, as Morris and Miller seem to believe? Coyne recognizes that to call evolutionary processes "contingent" does not mean, at a first level of analysis, "undetermined" but only "unpredictable." Yet Coyne proposes that at a deeper level the processes of evolution do lie on radically contingent grounds; he suggests that if quantum indeterminacy ultimately yielded these evolutionary processes, then evolution would be fundamentally contingent. When, however, Miller used quantum mechanics to argue that God might be lurking in the indeterminacy of subatomic processes, Coyne dismissed the supposition with the remark that Miller was "camping on the outskirts of creationism."[65] Both sides quote quantum mechanics for their own purposes.

Here it would be helpful to bring in David Hume, one of Darwin's favorite philosophers. Hume contended that "a wise man . . . proportions his belief to the evidence."[66] And since the sciences have proved to be a coherent, interdependent framework for understanding, together they stand as powerful evidence against any assumptions of miraculous interventions into the natural world, interventions that might covertly and undetectably slip into the natural world, changing this, modifying that, or orchestrating everything from an external vantage. To allow this would be to give up rational control of an enterprise that has proved extremely successful, and has been so only through control from within. Control from within occurs as rational actors continue to make discoveries warranted by evidence and to adjust the findings of the sciences to one another—it is an engine propelled by its own energies. So, following Hume's dictum, it would not be the part of wisdom to allow a remote possibility to outweigh a weighted probability. To allow miracles would be to thwart the rational character of science and destroy its integrity. At most, one can say that theistic evolution is a logical possibility, but that the evidence is heaped against it.

The new "natural theologians," as Coyne describes them, have attempted to caution against the liabilities of scientism, the belief that science is the exclusive mode of knowing. Coyne thinks such cautions are based on a faulty assumption, because science is in fact the only way of knowing the world. He challenges professors of literature and literary critics "to give me examples of truths actually *revealed for the first time* by literature."[67] But is this challenge so hard to meet? Keats declared that he had only heard rumors about the fabled realms of gold but never understood them till he "heard Chapman sing out loud and bold." Did he and others not then acquire some new knowledge and for the first time? Many an ancient Greek adolescent, as well as modern college student, has perhaps understood fragments of war, the elements of savage revenge, of blind rage, of the prideful stupidity of generals, of a father's tender love, and of a woman's passion for a beautiful but unworthy man—but did any see the thing whole before the Homeric songs orchestrated the intricate relationship of these elements? Those songs provide real experience of psychological and social behavior that generations of readers have found true, and have modeled their own behavior on. In a comparable way, there is scarcely a feature of Darwin's theory that had not been fragmentally known before he wrote, though something new was revealed in the "long argument" of the *Origin* that wove those features together.

Reciprocally, science makes use of metaphor—the special provenance of literature. When Darwin exclaims that "we behold the face of nature bright with gladness," he calls the reader's attention, by contrast, to the great life-destroying struggle that occurs behind a happy mask and cautions against being deceived by surface appearances.[68] "Natural selection" is itself a metaphor that structures the entire theory in unspoken ways; our different analyses in the body of this book indicate some of those possible ways. Models in science are in fact metaphors, instruments for understanding a phenomenon by employing more tractable considerations to get at the less tractable. The Cambridge philosopher Mary Hesse distinguished three types of analogies packed into the metaphors of science: a positive analogy, by which the model and the natural phenomenon are assumed to be alike; a negative analogy, by which they differ; and a neutral analogy, which suggests areas of investigation wherein one might find either further similarities or differences.[69] The positive analogy is pedagogically useful; the neutral analogy is useful as a guide to further research. Such metaphors in literature and science operate to acquaint us with aspects of the world hitherto unnoticed. Without the literary device of metaphor, Darwin would not have been able to stake his scientific claim, to make it plausible to his readers and to himself.

Bertrand Russell distinguished two kinds of knowing: knowledge by description, which depends on inferences drawn ultimately from foundational knowledge, and knowledge by acquaintance, which is that foundational knowledge.[70] The latter is immediate, noninferential awareness, an observation of some feature of the world, as when Galen, for instance, first dissected an eye and noted the five layers of the cornea. Without knowledge by acquaintance there can be no theoretical, inferential knowledge. But is knowledge by acquaintance in the sciences fundamentally different from the kind of knowledge by acquaintance illuminated by an arresting literary metaphor or graphic line of poetry, the kind that gives us for the first time immediate knowledge? Hasn't the last line of Randall Jarrell's "Death of the Ball Turret Gunner" jolted any number of naive high school students out of an obsession with the faux glory of the warrior? The sciences are deposits of different ways of knowing, some of which intersect with the kind of aesthetic awareness that literature provides. Salutary, then, is the caution that science is not the narrow and only road that leads to revelations about the world. To state this, of course, would not deny that physics, biology, and the social sciences have discovered quite reliable ways of knowing, just not the only or exclusive ways.

But does religion provide knowledge of any kind compatible with science? Of course, that depends on what you mean by religion. Coyne tells of many stupid and egregious decisions justified by religion—the Christian Science parents, for example, who allowed their daughter to die of bone cancer, choosing prayer over medical treatment.[71] No rational and moral person would defend the parents in their delusion, but likewise no rational and moral scientist should have sanctioned the Tuskegee experiments. Neither science nor religion makes bad decisions, individuals do. Scientific knowledge—certainly including evolutionary theory—gives actors the instruments to make informed, rational, and moral decisions. Does religion of any sort perform a similar function? Consider the view of Friedrich Daniel Schleiermacher (1768–1834).

In 1799, Schleiermacher, a member of a loose confederation of Romantic poets, philosophers, and scientists, published a tract entitled *On Religion: Talks to the Cultured People amongst Its Despisers*.[72] The despisers were very much like Coyne and friends, completely dismissive of religion. Without detailing the deep features of what Schleiermacher takes to be the kind of intuition—knowledge by acquaintance—grounding religious response, suffice it to say it is a feeling of dependency in light of the infinite character of the universe, a universe that operates according to scientific principles but yet lies still beyond the grasp of such principles, a mysterious beyond that seems to have no end. J. B. S. Haldane, conceptually arrested by this aspect of science, suspected that "the universe is not only queerer than we suppose, but queerer than we can suppose."[73] But we do, in our way, come to grips with nature. In the history of science, mysteries have gradually given way to human reason, but continue to reveal an ever greater vastness of the unknown—beyond our now conventional understanding of matter lies, perhaps, its further ground in mathematical entities called strings and beyond that in an imponderable dark matter and energy, all of which cannot but yield a feeling of dependency and respect for a universe that leads on to these glimmering mysteries and more beyond, perhaps to an infinity of budding universes. For Schleiermacher, the dogmas of Christianity and other religions were only metaphorical expressions of this fundamental feeling, this awareness of the power yet insufficiency of the human mind. This is not Gould's doctrine of separate magisteria, rather this view of religion is not merely compatible with science, it is necessary for the advancement of science. And, perhaps, for leading a coherent life, one in which the appreciation of poetry, art, and religion provide the same kind of experience that leads creative scientists to advance beyond their more pedestrian colleagues. Darwin was one such as these.