

# ELEVEN



## THE CASE FOR EVOLUTION

Life is too short to occupy oneself with the slaying of the slain more than once.

—T. H. HUXLEY, 1861

Creation and evolution, between them, exhaust the possible explanations for the origin of living things. Organisms either appeared on the earth fully developed or they did not. If they did not, they must have developed from preexisting species by some process of modification. If they did appear in a fully developed state, they must indeed have been created by some omnipotent intelligence, for no natural process could possibly form inanimate molecules into an elephant or a redwood tree in one step. If species were created out of nothing in their present form, they will bear within them no evidence of a former history; if they are the result of historical development, any evidence of history is evidence of evolution.

If species are the products of creation, what should we expect to see? According to the creationists, "The First Cause of all things must be an infinite, eternal, omnipotent, omnipresent, omniscient, moral, spiritual, volitional, truthful, loving, living Being!"<sup>1</sup> That is, the nature of the Creator is inferred from the creation. But this argument from design is a two-edged sword. Gerard Manley Hopkins may find that "the world

is charged with the grandeur of God," but Shakespeare can just as well say in *King Lear* that "as flies to wanton boys are we to the gods; they kill us for their sport."

If we find the natural world to be full of useless features, inadequate design, shoddy workmanship, and harshness or cruelty, we must either conclude that the personal Creator envisioned by creationists is cruel, thoughtless, and incompetent, or else conclude that He is indeed omnipotent, omniscient, and loving, but also capricious and arbitrary. But if the Creator acts at whim, without consistency or reason, we can make no predictions whatever: species may be well adapted or not, have useful or useless organs, and we are left ascribing them to the inscrutable acts of an inscrutable God. We are left without hope of explanation or understanding; and science, which searches for understanding by making and testing predictions, ceases to exist.

The case for evolution then has two sides: positive evidence—that evolution has occurred; and negative evidence—that the natural world does not conform to our expectation of what an omnipotent, omniscient, truthful Creator would have created. If the creationist replies that everything in the world, no matter how arbitrary, useless, or cruel, is just what we should expect of the Creator's infinitely inscrutable wisdom, he is playing Dr. Pangloss to our credulous Candide; and he is tacitly admitting that creationism can predict nothing, and so cannot be science.

We look at the design of organisms, then, for evidence of the Creator's infinite intelligence, and what do we see? A multitude of exquisite adaptations, to be sure: the bones of a swallow beautifully adapted for flight; the eyes of a cat magnificently shaped for seeing in the twilight. But if we look further, we find that the bones of the flightless dodo and penguin are also hollow, as if adapted for flight; and that the mole and the cave salamander also have a lens and retina that serve no function. Every organism has such vestiges of structures that can only be the useless remnants of past adaptations. Why should we have wisdom teeth, unless our jaws have become shorter, so that our ancestors' teeth no longer fit? Why should we, like other primates but unlike almost all other vertebrates, require vitamin C in our diet, unless we stem from ancestors who got enough vitamin C in their diet of fruit? Do we find here evidence of wise design?

Look further in the living world and you find animals and plants that make do with inferior adaptations. Primates manipulate their food with a dexterous opposable thumb, but the giant panda makes do with a clumsy thumblike structure modified not from the first finger but from

a wrist bone. Consider how immensely useful photosynthesis would be to animals when food is in short supply. Some marine animals such as corals indeed make use of photosynthesis by harboring algae in their bodies, but no higher animals have been endowed with their own photosynthetic mechanism. Compound eyes are one of the major adaptations of adult insects such as butterflies and bees; yet no caterpillar in the world has them, however useful they might be. Is it easier to believe that an omnipotent Creator withheld adaptations that would make life easier, or to believe that this is not the best of all possible worlds, and that species make do with the best genetic variations that happen to become available?

When we compare the anatomies of various plants or animals, we find similarities and differences where we should least expect a Creator to have supplied them. Is it not strange that a Creator should have endowed bats, birds, and pterodactyls with wings made out of the same bony elements that moles use for digging and penguins use for swimming? Is it not stranger still that instead of modifying these bones for flight in the same way, the Creator should have decreed that the bat's wing be made by lengthening four fingers, the pterodactyl's by lengthening only one finger, and the bird's by shortening the hand and equipping it with feathers? If evolution happens, we should expect different organisms to evolve different solutions, by chance, to similar problems; but an omniscient Creator shouldn't have to experiment with different designs. Birds and mammals, being warm-blooded, have only one aortic arch instead of two as in amphibians and reptiles, for more efficient transport of blood from the heart; but can any creationist explain why birds retain the right aortic arch while mammals retain the left one?

Embryology, too, reveals that related species are similar in ways that make no adaptive sense. The embryos of whales and anteaters develop teeth and then absorb them before birth. This makes sense if they carry in their genes the imprint of their history; but could any creationist have predicted these embryonic patterns by the argument from design? Or is the Creator trying to trick us into believing in evolution?

Molecular biology finds at every turn patterns that make sense in an evolutionary interpretation, and no sense in a creationist view of the world. The similarity of DNA is greatest not between animals that have similar adaptations and similar modes of life, but between species that on anatomical grounds are believed to be evolutionary relatives. The DNA of parasitic worms is similar not to that of other parasites but to the DNA of their nonparasitic relatives. Can this be part of a Creator's design? Can we attribute to an omniscient Creator the fact that bacteria

have "silent" genes that are never expressed and appear to have no function?

The modern theory of evolution says that organisms should experience random mutations that are not designed to be adaptive but may turn out fortuitously to be so; and that adaptation proceeds by natural selection—the success of the fitter at the expense of the less fit. The creationists admit that species can undergo limited adaptive changes by the mechanism of mutation plus natural selection. But surely an omniscient and omnipotent Creator could devise a more foolproof method than random mutation to enable his creatures to adapt. Yet mutations do occur, and we have experimental demonstration that they are not oriented in the direction of better adaptedness. How could a wise Creator, in fact, allow mutations to happen at all, since they are so often degenerative instead of uplifting? According to the creationists,<sup>2</sup> there is "a basic principle of disintegration now at work in nature" that we must suppose includes mutation. But why should the Creator have established such a principle? Didn't He like the perfection of His original creation?

And natural selection: what cruelty and waste it seems to entail! As the creationists say, surely the God of the Bible could not have invented such a mechanism to build adaptations and maintain them. But however distasteful it may appear, natural selection is found operating in every species that has ever been studied. It would be hard to imagine a crueler instance of natural selection than human sickle-cell anemia—part of the population being protected against malaria at the expense of hundreds of thousands of people condemned to die because they have inherited a disastrous gene that happens to be worse for the malarial organism than for some of the people who carry it. And such examples are not limited to our sinful species; do not suppose that sickle-cell anemia is part of the fall from grace. In the forests of South America there is a species of fruit fly in which exactly the same principle remorselessly kills many of the offspring of every fly: heterozygotes for a particular gene survive, but many of their homozygous offspring die in their infancy.<sup>3</sup>

And what are we to make of those cases of natural selection run amok? Are they instances of the divine wisdom? Does it accord with the divine sense of harmony that male elephant seals should battle so furiously for females that great numbers of them die of bloody wounds? Did God require the peacock to carry such long feathers that it can hardly fly, just so that it could attract females and insure the propagation of the species?

Looking to ecology, we should expect balance and harmony in a

perfect creation. But the "balance of nature" is a myth created by visionary Victorians and perpetrated upon us by the solemn voice-overs on television natural history shows. Yes, there is a nitrogen cycle, whereby various bacteria transform atmospheric nitrogen into compounds that plants and animals can use. But such bacteria are far from ubiquitous, and there are many places on earth where usable nitrogen and other essential elements are in very short supply. True, predators sometimes prevent population explosions of their prey. But very often they do not. Even in natural ecosystems untouched by human disturbance, plague locusts and other species erupt in vast numbers, lay waste the land, and perish by the millions. Unless prey species have adequate defenses, their predators and parasites do indeed extinguish them. The fungus that extinguished the chestnut and the rats that have brought many species of island birds to extinction have not been stayed by the divine desire for natural harmony. A wish for harmonious coadaptation should have impelled the Creator to endow species with the ability to check their own increase and stop short of overpopulation, but species do not have this ability. If species do stay within certain limits of population size, it is only because of the forces of nature that kill thousands for every one that survives.

And why should there be more than a million species of animals and more than half a million of plants? Creationists know why: everything was created to serve a purpose, and that purpose is profoundly anthropocentric. "The earth was created specifically to serve as man's home," and "all . . . created systems must in some way be oriented man-ward, as far as purposes are concerned."<sup>4</sup> They would have us believe that the 250,000 known species of beetles, and untold numbers of undescribed species, exist to serve humanity; that Antarctic birds possess unique species of lice for the benefit of man; that the lung worms that infest snakes and the schistosome worms that kill hundreds of thousands of people each year are part of God's gift to the human species. Hundreds of thousands of species of ammonites, brachiopods, graptolites, alcyonarians, and other extinct invertebrates, of which not one person in a million has ever heard, existed and died out millions of years before humans walked the earth; was their "purpose" only to make us puzzle over their remnants in the rocks, deluding us into believing in evolution?

Finally, the fossil record can never be fitted into a creationist interpretation. Nowhere does the absurdity of their arguments become more evident than in their frantic, fanciful attempts to explain the fossil record and the fact that more than 90 percent of the species the Creator is

supposed to have created became extinct, just as if no one cared. At least the pre-Darwinian creationists, in their devoted search for enlightenment, supposed that God might have indulged in dozens or hundreds of successive creations, resulting in the orderly sequence of fossil faunas. But because fundamentalist creationists have to squeeze all of creation into six days, the only way they can explain the geological record is to invoke great cataclysms associated with the Biblical flood. They visualize gigantic currents of water, enough to cover the world, pouring from the skies, accompanied by vast volcanic explosions and massive movements of the continents, great increases in the temperature and turbidity of the oceans, and finally the deposition of sediments as the oceans settled. "The very complexity of the model makes it extremely versatile in its ability to explain a wide diversity of data (although, admittedly, this makes it difficult to test)."<sup>5</sup> That's the understatement of the decade.

Now listen to some of the "obvious predictions" of the flood model.<sup>6</sup> Animals that lived together in the same ecological communities would normally be buried together (despite the great vortices and earth movements?). Marine fishes would be preserved in higher rocks than invertebrates because "they live at higher elevations" (as if fishes and invertebrates did not coexist in every marine community in the world). Amphibians and reptiles would be fossilized in still higher rocks because they are found at the interface between land and water (but how is it that marine shells are found on mountaintops, and why weren't amphibians swept into marine sediments?). Few birds would be found at all, because of their mobility (where did most of the birds go? I don't know any birds that can fly steadily, without food, for forty days and forty nights). Higher animals such as land vertebrates would be segregated vertically in order of complexity, because the "more diversified" animals could escape the cataclysm longer and move to the mountaintops (could mice really move faster than the small, swift dinosaurs? And why didn't the winged pterodactyls make it up to the top?).

As long as we're entertaining such thoughts, let's go a bit further. The creationists' source of truth is Genesis, wherein we find the story of the flood. Genesis also says that God commanded Noah to take into the ark a pair of every living thing that creeps upon the face of the earth, and we are told that Noah obeyed the Lord's command. But if all the millions of extinct species in the fossil record perished in the flood, Noah didn't really obey the Lord, even though the Bible says he did. If he did take them in, the Lord, for unknown reasons, must have let them perish after they left the ark. Nonetheless, at least the million species of animals and presumably the half million or more plants that

we have today survived. They must have been in the ark—all 2 million individual animals. Australian kangaroos, South American boa constrictors, Arctic foxes, New Zealand kiwis, and 250,000 species of beetles. Not to mention all their parasites. And, assumedly, food for a million species for a month or so. I suppose all these species lived together in the Middle East, within easy reach of the ark, and that Noah was the best animal collector in the history of the world. Don't forget, of course, the thousands of species of fresh-water fishes. They couldn't have survived in a raging, salty sea, so the ark must have had a big aquarium in it.

Can you believe that any grown man or woman with the slightest knowledge of biology, geology, physics, or any science at all, not to speak of plain and simple common sense, can conceivably believe this? Can you for one moment imagine that this is supposed to be taught to children in the name of science? With or without the story of the ark, the flood cannot conceivably account for the facts of geology and paleontology. Not only are the creationists who propound such nonsense abysmally ignorant of, or blind to, the most elementary facts of biology and geology; not only are they willing to invent stories that defy every law of nature to save their myth of creation; but they have the arrogance to claim that these stories are "science," and that their "science" is just as good as that of thousands of geologists and biologists who have devoted their lives to careful experimentation, observation, and logic. What conception can a young person have of how to seek knowledge if he or she learns that a myth of gigantic earth cataclysms unlike anything known to science, a myth that contains within it the most absurd contradictions and defies every fact of biology, deserves "equal time" with hypotheses that have been tested and supported by countless careful experiments and observations?

On the positive side of the ledger, let me briefly summarize the evidence for evolution. First, the theoretical mechanisms of evolutionary change have been abundantly documented by experiment and observation. Mutations in every kind of characteristic—anatomical, physiological, biochemical, behavioral—are known to occur. Some of these are indeed unconditionally harmful, but some are positively beneficial. Most mutations do not damage the organism irreparably, but merely cause slight changes in a characteristic—the size or shape of an organ, the activity of an enzyme. The genetic variations that arise by mutation accumulate, so that every population contains an immense

amount of genetic variability that enables it to change rapidly when environmental conditions are altered.

Natural selection operates when some genetic variants are more successful in surviving and reproducing than others. When the environment isn't changing, selection tends to eliminate genetic variants that deviate from the most favored types in any direction. When the environment changes, formerly inferior variants may become superior and replace the prevalent types. Both forms of natural selection—maintenance of the status quo, and change toward a better-adapted form—have been observed many times in natural populations of plants and animals. Different populations of a species adapt to different environmental conditions. If they acquire differences that prevent them from mating with each other, they become different species. The evolution of such reproductive barriers has also been observed both in experimental situations and in the wild.

Thus we know from direct observation and experiment that the ingredients of evolutionary change are real and potent, just as a geologist knows that erosion is a fact of physical geology. Over the course of millions of years, it is inconceivable that erosion and other observable geological mechanisms should fail to create great gorges and canyons; and it is just as difficult to imagine that mutation and natural selection should fail to create great changes in species over vast periods of time.

The changes that mutation and natural selection can bring about in any one species within the short span of human observation are limited in degree; we can see one species of fly give rise to another, but we do not expect to see flies transformed into fleas in laboratory experiments. That would be asking too much. Such great alterations can only be formed by successive transformations of intermediate steps. If, however, we look at any major group such as the insects, we see a continual gradation of differences from the very slight to the very great. Different families or orders of insects or mammals differ only in degree: they have the same structures, but many of the structures have been greatly modified in size, shape, and arrangement.

But science does not require direct observation to verify its hypotheses; its most powerful technique is the testing of predictions. We cannot observe the orders of mammals diversify from mammal-like reptiles, nor the great diversity of living things flower forth from a single Precambrian ancestor. But we can test the predictions of the hypothesis that living things have a common ancestry.

We predict, first of all, that all living things should share certain common characteristics, and they do. All species, from bacteria to mam-

mals and trees, use the same genetic code, in which the same nucleotide sequences code for the same amino acids. All species use "left-handed" amino acids to make proteins out of. (Amino acids, like other organic molecules, come in two forms that are mirror images of each other but otherwise have the same chemical properties.) From a chemical point of view, this universality is not necessary. Different genetic codes would have served equally well to make proteins out of, and right-handed amino acids could have worked just as well as left-handed ones. The only possible reason for these chemical universalities is that living things got stuck with the first system that worked for them. Once the genetic code was established, no species was ever free to try a new one. A mutation that caused the nucleotide sequence UUU to code for glycine instead of phenylalanine would have messed up all the species' proteins. Similarly, a species whose ancestor used only left-handed amino acids wasn't free to use right-handed ones. They wouldn't have fit properly into the proteins. Where a Creator would have been free to use different biochemical building blocks for different species, evolution was not free: the history of the earliest organisms determined everything that happened thereafter.

The hypothesis of evolution predicts, next, that organisms should share various characteristics in a hierarchical arrangement. As species split and then give rise to more species, they will form a phylogenetic tree. All the members of any major branch of the tree will share characteristics that diverged early in history. Within these major branches, related "twigs" that have branched off more recently will share their own special sets of more newly evolved features.

Allowing for the reversals and parallelisms that do sometimes occur, the world's species do fit this hierarchical arrangement very well. Within the vertebrates, we distinguish major branches such as fishes and tetrapods—the four-legged animals that have a particular arrangement of bones in their limbs. The tetrapods divide into amphibians, which lack an amnion, and the reptiles, birds, and mammals, which possess one. Within the mammals, we distinguish primitive species such as marsupials, which lack a placenta, from the more advanced placental mammals, and so on. The fact that we can use a few characteristics to make a tree-like diagram accords with the idea of evolution, but of course it doesn't prove that evolution has occurred. However, the hypothesis of evolution says that there must be only one real evolutionary tree, and if this is so, then it should be possible to find different sources of data that all independently give the same evolutionary diagram. In other words, if structural features indicate that placental mammals diversified



after mammals branched off from reptiles, independent lines of evidence should indicate this too.

In fact, there are many independent lines of evidence. One is geological: knowing that the continents have been drifting apart ever since the Permian, we predict that groups which supposedly evolved late in evolutionary history should be more restricted to one or a few continents than groups which supposedly evolved early. This is in fact the case. The fossils of mammal-like reptiles are broadly distributed over all the continents, and so are most of the primitive mammals such as marsupials. But orders and families of mammals such as carnivores and hoofed mammals, which are so similar to each other that they are thought to have diverged more recently, are more restricted in distribution. Many of these groups have never been found, either as fossils or living species, in Australia or South America, which broke away from the other landmasses before groups such as elephants, horses, or apes evolved.

Another independent line of evidence is biochemical. The evolutionary classification of vertebrates was derived before Watson and Crick ever thought of DNA as the genetic material. Since that time it has been possible, either directly by examining the DNA, or indirectly by examining the proteins that the DNA codes for, to measure the genetic similarity of species. Almost invariably these investigations give the same answer that evolutionary taxonomists had found on the basis of morphology: pigs and cows are more similar to each other than they are to dogs; these together are more similar to each other than to primitive mammals such as kangaroos; all mammals are more similar to each other than to reptiles; and so on. Mounting molecular evidence indicates that many of the differences and similarities in DNA sequence are not due to similarities in the organism's structure and function. Rather, much of the variation between species at the level of DNA seems to be in "neutral" changes that have developed by chance (genetic drift): the genes differ somewhat from species to species in their exact nucleotide sequence, but the proteins that the genes make serve the same function. If this is true, divergence in structure has occurred independently of much of the divergence in DNA, so that the two sources of evidence of degree of relationship reinforce one another and are not merely two ways of looking at the same thing.

A major prediction of evolution is that organisms should carry within them the evidence of their history. The evidence of history lies partly in embryology (all vertebrates have similar embryos; terrestrial salamanders go through an "aquatic" larval stage before they hatch from

the egg; fetal anteaters have teeth); partly in behavior (our body hairs are erected when we are afraid, just as in the "fight or flight" reaction of more heavily furred mammals); and partly in the useless vestigial structures that every species possesses (there is no functional explanation for the rudimentary eyes of cave animals; the tiny, useless legs of many snake-like lizards; the vestiges of the pelvis in pythons). The effects of history are abundantly evident in the distribution of organisms. There are no native land mammals in Hawaii, not because they cannot survive there, but because they evolved on continents and couldn't cross the Pacific.

Finally, there is the evidence of the fossil record. We predict that if evolution has occurred, old rocks will forever lack fossils of many species that had not yet evolved. We have never found a fossilized mammal or flowering plant in Silurian deposits, and we never will. We should and do find, on the contrary, that the early rocks contain organisms such as lungfishes and cockroaches that are believed to be ancient groups on the basis of entirely independent evidence from the anatomy and biochemistry of their living representatives. Similarly, groups such as elephants and ants which the anatomy of living species tells us are more recently evolved do not appear except in more recent geological formations. On occasion we should and do find gradual transformational forms from primitive ancestors to modified descendants in exceptionally good fossil deposits. The African record of human evolution is just one of the many cases in which transitional series from ancestors to more modern descendants have come to light.

To pass from primordial molecules to the first cell, and from the first cell to complex animals and plants, had to take time—billions of years. Physicists with their radioactive clocks, astronomers with their "red shifts," geologists with their measurements of continental drift and other earth processes, biologists with their coral clocks—all converge on the same answer: the earth is more than 4 billion years old.

The great age of the earth is a fact. The drift of continents is a fact. It is a fact that the earth has supported different species at different times. It is a fact that species are related to each other by descent. It is a fact that beneficial mutations alter species in every imaginable way. It is a fact that the environment selects some genetic variations for survival and others for extinction. It is a theory that the processes of mutation, recombination, genetic drift, natural selection, and isolation can account for the historical products of evolution, but it is a fact that evolution has occurred. That is the message of the hundred years of biology, geology, physics, and chemistry that have elapsed since Darwin's death.

can in fact be observed or tested. If religion is defined as including any set of beliefs that touches on ethics and values, then evolution is not a religion, because it describes what has occurred, not what should occur.

5. *The order of the universe, and the adaptations of organisms to their environments, are evidence of intelligent design and purpose.*

Order can be observed to arise from the action of natural laws and physical processes, and is not evidence of design.

## II. Natural Law

6. *Because the second law of thermodynamics holds that entropy (disorder) increases, all change must be degenerative, and greater complexity could never have evolved.*

The second law applies only to closed systems. Organisms, which exist in open systems, can capture energy and use it to build greater chemical order, and they do so all the time.

## III. Biological Evolution

7. *It is infinitely improbable that even the simplest life could arise from nonliving matter.*

The formation of any particular nucleic acid sequence by chance is very improbable, but the chance of forming one or another viable form is very high.

Under conditions resembling those on the prebiotic earth, simple organic molecules actually form from elementary constituents (ammonia, methane, etc.), and assemble themselves into self-replicating nucleic acids which mutate and are altered in frequency by natural selection, all in the laboratory.

8. *Mutations are harmful, and do not give rise to new characteristics.*  
Mutations that have "large" effects are usually harmful, but most mutations have small effects, and many of these are demonstrably beneficial under certain environmental conditions.

9. *Natural selection cannot create new characteristics; it is a conservative process that merely eliminates unfit mutants.*

First, most characteristics that appear in evolution aren't really new; most are changes in size, shape, developmental timing, or organization of preexisting characteristics. Second, natural selection acts as an editor, not an author: it shapes adaptive characteristics out of the chaotic new variations that arise by mutation and genetic recombination. Third, the evolution of important new

# A P P E N D I X

## SOME CREATIONIST ARGUMENTS, AND SOME APPROPRIATE RESPONSES

I list here some of the common creationist claims, each with a capsule counterargument. Most of these are developed fully in the body of the text.

### I. Philosophical and Scientific Issues

1. *Evolution is outside the realm of science because it cannot be observed.*  
Most of science depends not on direct observation, but on testing predictions that derive logically from hypotheses. We do not know the structure of an atom or a DNA molecule from direct observation.
2. *Evolution cannot be proven.*  
Nothing in science is ever proven; we merely achieve greater and greater confidence in the validity of our hypotheses as more data support or fail to refute them.
3. *Evolution is not a testable hypothesis because it could not be refuted by any possible observation.*  
Many conceivable observations, such as mammalian fossils in Precambrian rocks, could refute the hypothesis of evolution.
4. *Evolution is a religion because it is based on unobservable processes and because it includes bidden concepts of ethics, values, and ultimate meanings.*

Belief in evolution does not require faith, because the processes

characteristics by natural selection has been observed frequently, as in the development of new metabolic capacities in bacteria.

10. *Chance could not be responsible for the origin of complex organisms, which therefore bear evidence of design.*

Although mutations arise by chance, they succeed or fail to become established in a species by natural selection, which is the antithesis of chance.

11. *Natural selection is an untestable, tautologous concept. The "fittest" are those who survive, who in turn are labeled the fittest.*

Given an understanding of the relation of each of two forms to an environment, one can predict which will more readily survive and reproduce; thus testable predictions about natural selection can be and have been made. It is also possible to find genetic changes that are not caused by natural selection, which shows that natural selection is not automatically invoked, by circular argument, to explain all evolutionary change.

12. *A new structure would not have any selective advantage when it first appears in a rudimentary condition, and so could not develop at first by natural selection.*

Even complex organs such as the eye are often represented by less complicated structures in more "primitive" species, in which they are fully functional. Moreover, not all changes are brought about by natural selection; some features become elaborated because of their correlation with the growth of other features, and only then become useful.

13. *No fossils have been found that exemplify an incipient structure evolving into a subsequently useful feature.*

This is not true; the fossil record provides many examples. One case, described in the text, is the incipient ridges on the teeth of early horses that subsequently became greatly elaborated as an adaptation for grinding vegetation.

14. *If gradual evolution had occurred, there would be no gaps among species, and classification would be impossible.*

Many disparate organisms are connected by intermediate species, and in such cases classification is arbitrary. In many other cases gaps exist because of extinction.

15. *Despite a rich fossil record, transitional intermediates between ancestors and descendants are not found in the fossil record.*

The modern genetic theory of evolution holds that adaptation to new conditions proceeds rapidly, so that few intermediates are likely to be found. Even so, many cases of evolutionary transitions

from one species to a related species are known in the fossil record, and the gradual origin of several groups (e.g., ammonites from belemnites, mammals from therapsid reptiles, horses from condylarthrs) is well documented by the fossil record. *Archaeopteryx*, contrary to creationists' claims, is not a full-fledged bird, but a reptile with a few avian characteristics such as feathers.

16. *If evolution is true, why should "living fossils" such as the coelacanth and the horseshoe crab have evolved little for hundreds of millions of years?*

If a species is adequately adapted to its environment, there is no reason to expect it to continue to evolve new adaptations.

17. *Homologous anatomical structures, and similarities in embryonic development, are examples of a common design used by the Creator, not of common ancestry.*

Of course anything can be "explained" by the Creator's desires, since we have no way to obtain information about the Creator. But many homologous structures make no adaptive sense, and do not conform to any optimal design that we can understand. There are no design constraints that require sharks and humans to have similar embryos and yet develop into completely different organisms.

18. *Vestigial structures are not vestigial but functional.*

There is not the slightest reason to think that many vestigial structures, which violate rational design, have any function. The pelvic bones of pythons and the rudimentary wings of many insects have no known function, and related species of snakes and insects lack them altogether.

19. *The fossil record is not an objective time sequence, because it is already assumed that evolution occurred, and only then are the rocks "ordered" by their fossil contents.*

In fact, the geological ordering of fossil strata was made by preevolutionary geologists who believed in creation. Moreover, radioactive dating and other methods are also used to establish a relative geological sequence.

20. *There is no proof that radioactive decay occurs at a constant rate, and hence no proof that the earth is billions of years old.*

The theory of physics, and the failure to find any factors that could alter rates of radioactive decay, provide a solid foundation for radioactive dating. Radioactive dates are consistent with many other sources of evidence indicating that the age of the earth, solar system, and universe must be measured in billions of years.



21. *Geologists are abandoning the principle of uniformitarianism; as a result, explanation of geological features, such as the fossil record, by catastrophes such as a universal flood, is equally plausible.*

Uniformitarianism holds that only presently observable natural forces have operated in the past, as they do today, although their rates can vary. Even at the most rapid rates known to exist, natural forces cannot account for geological features such as continental drift or sedimentation except on a time scale of many millions of years. The ordering of fossils, and many other features of the fossil record, cannot conceivably be explained either by a single catastrophe or a series of catastrophes.

22. *No one can know events that occurred before there were people to observe and record them; thus past evolutionary events can never be known.*

Direct observation is not the only source of reliable evidence; and in fact direct observation often provides untrustworthy evidence. Past events can be reliably inferred by logical deduction, using a variety of methods that are common to all historical sciences.

#### IV. Human Evolution

23. *There are no intermediate fossils between humans and apes. Australopithecus walked on all fours like modern apes, and had an apelike skull. It was merely an ape.*

The anatomy of australopithecines, including the recently discovered form called *Australopithecus afarensis*, clearly indicates an erect posture, coupled with a rather apelike skull with a small brain. Later hominid fossils clearly approach modern humans in successive steps, in several features such as brain size and dentition. Associated stone tools also show progressive complexity of design. *If races diverged in skin color and other trivial features, why haven't they diverged in intelligence, which is so critical to survival?*

Different characteristics experience different patterns of selection. Intelligence was, very likely, evolved to its modern degree in ancestral human populations before they spread into new areas, where divergence in skin color may have been locally adaptive (or may have occurred by genetic drift). Because of the high survival value of intelligence, it would experience stabilizing selection to maintain the same high level everywhere. This is not at all the "unsolved puzzle" the creationists make it out to be.

25. *Evolutionists in Darwin's day were racists, and the very concept that*

*each race has taken a long time to evolve leads to racism. Racism is the concept that each race has a long, separate evolutionary history.*

Racism is, on the contrary, the social attitude that holds that the characteristics (especially personal and social) of an individual must conform, a priori, to those that are thought (usually without evidence) to be typical of the race to which the individual belongs, without taking into account the existence of individual variability. It is not founded at all on the concept of evolution. Evolutionary divergence in characteristics such as skin color does not at all imply that other characteristics such as intelligence have diverged. If nineteenth-century evolutionists were racist (and not all were), they merely shared the nonscientific assumptions of their society. *26. There is an unbridgeable gap in intelligence and emotions between humans and all other species that cannot be accounted for by evolution.*

The mental characteristics of *Homo sapiens* are indeed developed to a far greater degree than seems to be true of any other species, yet most of the mental faculties we have seem to be present in more rudimentary form in other primates and mammals. If cognition, emotion, etc. have a physical basis in the brain, which is the working assumption of psychology, then the physical basis for cognition and consciousness could evolve, just as other physical features do.

#### V. General Issues

27. *Quotations from many eminent evolutionists show that biologists have abandoned the concept of gradual evolution by natural selection. Darwin was wrong, and the entire study of evolution is in disarray.*

Most of the quotations cited by creationists in justification of this posture are from evolutionists who claim that (a) gradual transitions between species are uncommon in the fossil record; (b) many characteristics of species do not appear to be adaptations; (c) evolution may proceed by large mutational changes as well as small ones; (d) the theory of natural selection doesn't explain certain major events and trends in the overall history of life.

Point (a) is taken by evolutionists to mean that evolution often occurs very rapidly, on a very local geographic scale, as is often demonstrably the case. This in no way contradicts traditional evolutionary theory. Point (b) has also been recognized by evolutionists ever since Darwin; many factors besides natural selection govern the direction and rate of evolutionary change. Point (c) is largely a matter of defining some mutations as "large" in effect and

others as "small"; there is, in reality, a complete spectrum of effects. Point (d) is an important recognition that the forces of mutation and natural selection that adapt a species in the short run may not be correlated with its chance of survival in the long run. The factors that cause ultimate extinction of some species and not others require more research than they have received, and a higher-level theory that includes traditional neo-Darwinian theory may be required. The evolutionists quoted do not deny the validity of evolutionary theory but are seeking to expand it to cover a broader range of phenomena. In most respects, Darwin is perceived to have been right, but a lot of the details of how evolution operates are still being worked out. This is evidence not of disarray in the science, but of healthy progress in the search for more complete explanations.

28. *Evolution should not be taught because it leads to a materialistic, amoral philosophy of "might makes right."*

The philosophical or ethical implications of any scientific statement do not bear on its scientific validity; neither they nor our desires make the statement either right or wrong. Ethics and philosophy are not part of science, and no moral lessons about how we should behave can logically be deduced from evolution or any other science. Scientific statements, whether in physics or biology, are materialistic in the sense that they explain natural phenomena by natural, material causes; they are amoral in that they describe what is, without making value judgments about whether it ought or ought not to be. The answers to ethical and moral questions must be found outside of science.

#### RECOMMENDED FURTHER READINGS

Although I am averse to supporting the creationist cause financially by buying their publications, I must recommend some creationist literature as the surest antidote to believing the creationist line. Many publications of Creation-Life Publishers, P.O. Box 15666, San Diego, California 92115 will do nicely. I have quoted most extensively from *Scientific Creationism* (Public School Edition), edited by H. M. Morris, and from *Evolution: The Fossils Say No!* by D. T. Gish. *The Troubled Waters of Evolution*, by H. M. Morris, contains almost the same material but is more straightforwardly religious in tone. *The Genesis Flood*, by H. M. Morris and J. C. Whitcomb, presents a "scientific exposition" of creation and the flood. *The Early Earth*, by J. C. Whitcomb, "shows how God's Word refutes any type of theistic evolution."

*Creation/Evolution* (P.O. Box 5, Amherst Branch, Buffalo, New York 14226) is a quarterly publication dedicated to promoting evolutionary science and covers current creationist political activities. Issue 7 (Winter 1982) has a useful article, "Answers to the Standard Creationist Arguments," by K. Miller.

*The American Biology Teacher* (11250 Roger Bacon Drive, Reston, Virginia 22090) is a must for teachers and has had numerous useful articles, including:

Alexander, R. D. 1978. "Evolution, Creation, and Biology Teaching."

ABT 40(2):91-104.

Callaghan, C. A. 1980. "Evolution and Creationists' Arguments." ABT 42(7):422-25.

Miller, K. R. 1982. "Special Creation and the Fossil Record: The Central Fallacy." ABT 44(2):85-89. (An important exposition of how the flood scenario is essential to the creationist argument, and why it is absurd.)

Hughes, S. W. 1982. "The Fact and the Theory of Evolution." ABT 44(1):25-32. (Includes a good capsule review of the coverage of evolution by high school textbooks.)

On the legal front, the important decision in *McLean v. Arkansas Board of Education* was reprinted in full in *The American Biology Teacher* 44(3):172-79 (March 1982), and in *Science* 215:934-43 (February 19, 1982).

#### SOME OTHER USEFUL ARTICLES INCLUDE:

Brush, S. G. 1981. "Creationism/Evolution: The Case Against 'Equal Time.'" *The Science Teacher*, vol. 48, no. 4.

Asimov, Isaac. 1981. "The 'Threat' of Creationism." *New York Times Magazine*, June 14, 1981. Ideal for classroom discussion and for enjoyment of his spirited style.

Cloud, P. 1977. "Scientific Creationism—A New Inquisition Brewing." *The Humanist* 37:1.

Nelkin, D. 1976. "The Science-Textbook Controversies." *Scientific American* 234(4):33-38. Analyzes reasons for creationist and other attacks on science curricula.

Skow, J., et al. 1981. "The Creationists." *Science* 81, pp. 53-60 (December). A succinct summary of who they are and how they operate.

Brush, S. G. 1982. "Finding the Age of the Earth by Physics or by Faith?" *Journal of Geological Education* 30:34-58. A thorough analysis of radioactive dating and how the creationists deal with it.

## BOOKS:

- Stebbins, G. L. *Processes of Organic Evolution* (Englewood Cliffs, N.J.: Prentice-Hall, 1971). A short, elementary introduction to the theory of evolutionary change. For introductory college courses.
- Stansfield, W. D. *The Science of Evolution* (New York: Macmillan, 1977). A somewhat more advanced textbook.
- Dobzhansky, Th., F. J. Ayala, G. L. Stebbins, and J. W. Valentine, *Evolution* (San Francisco: Freeman, 1977).
- Futuyma, D. J. *Evolutionary Biology* (Sunderland, Mass.: Sinauer, 1979). This and the preceding book are the most comprehensive current college textbooks on the subject.
- Stebbins, G. L. *Darwin to DNA, Molecules to Humanity* (San Francisco: Freeman, 1982). This is one of the few recent books designed to explain evolution for the general reader, by one of the leaders in the field.
- Cloud, P. *Cosmos, Earth, and Man* (New Haven: Yale University Press, 1978). A very readable nontechnical discussion of the history of the universe, the earth, and living things.
- Johanson, D. and E. Maitley, *Lucy: The Beginnings of Mankind* (New York: Simon & Schuster, 1980). A lively account of one anthropologist's fossil discoveries and interpretation of human evolution; conveys a nice sense of what is and isn't known, and what to do in order to know more.
- Gould, S. J. *The Panda's Thumb* (New York: Norton, 1980). Superb essays about evolution and science by perhaps the best writer in science today.
- Godfrey, L., ed., *A Century After Darwin* (Boston: Allyn & Bacon, 1983). A moderately technical collection of essays treating the development of evolutionary thought since Darwin. Touches on creationism only slightly.

## THE CREATIONIST DEBATE IS EXPLICITLY TREATED IN THE FOLLOWING BOOKS:

- Eldredge, N. *The Monkey Business* (New York: Washington Square Press, 1982). A short, very nontechnical treatment of the arguments.
- Newell, N. *Creation and Evolution: Myth or Reality?* (New York: Columbia University Press, 1982). For the general reader, treating especially paleontological aspects.
- Kitcher, P. *Abusing Science: The Case Against Creationism* (Cambridge,

Mass.: MIT Press, 1982). A philosopher's detailed analysis of creationist arguments.

Godfrey, L., ed., *Scientists Confront Creationism* (New York: W. W. Norton, 1983). A collection of nontechnical essays, by scientists from many fields, that refute creationist arguments on astronomy, geology, biology, and anthropology.