3.7 The Debate over "Scientific Creationism" and Intelligent Design Creationism

Scientific controversy over the fact of evolution ended in the late 1800s, when the evidence reviewed in Chapter 2 simply overwhelmed the critics. Whether natural selection was the primary process responsible for both adaptation and diversity was still being challenged until the 1930s, when the works of the Modern Synthesis provided a mechanistic basis for Darwin's four postulates and unified micro- and macroevolution. Evolution by natural selection is now considered the great unifying idea in biology. Although scientific discourse about the validity of evolution by natural selection ended well over a half-century ago, a political and philosophical controversy in the United States and Europe still continues (Holden 1995; Kaiser 1995). What is this debate, and why is it occurring?

Creationists want the Theory of Special Creation to be taught in public schools, even though it was dismissed as a viable alternative to the Theory of Evolution by Natural Selection over a century ago.
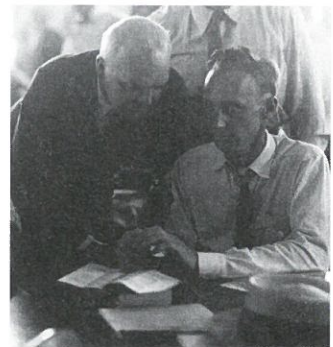
History of the Controversy

The Scopes Trial of 1925, popularly known as the Monkey Trial, is perhaps the most celebrated event in a religious debate that has raged since Darwin first published *On the Origin of Species* (see Gould 1983, essay 20; Larson 1997). John Scopes (Figure 3.22) was a biology teacher who gave his students a reading assignment about Darwinian evolution. This was a clear violation of the State of Tennessee's Butler Act, which prohibited the teaching of evolution in public schools. William Jennings Bryan, a famous politician and a fundamentalist orator, was the lawyer for the prosecution; Clarence Darrow, the most renowned defense attorney of his generation, led Scopes's defense. Although Scopes was convicted and fined $100, the trial was widely perceived as a triumph for evolution because Bryan had suggested, while on the stand as a witness, that the six days of creation described in Genesis 1:1–2:4 may each have lasted far longer than 24 hours. This was considered a grave inconsistency, and therefore a blow to the integrity of the creationist viewpoint. But far from ending the debate over teaching evolution in U.S. schools, the Scopes trial was merely a way station.

The Butler Act, in fact, stayed on the books until 1967; it was not until 1968, in *Epperson v. Arkansas,* that the U.S. Supreme Court struck down laws that

Figure 3.22 Scopes on Trial
John Scopes, right, confers with a member of his defense team.

prohibit the teaching of evolution. The court's ruling was made on the basis of the U.S. Constitution's separation of church and state. In response, fundamentalist religious groups in the United States reformulated their arguments as "creation science" and demanded equal time for what they insisted was an alternative theory for the origin of species. By the late 1970s, 26 state legislatures were debating equal-time legislation (Scott 1994). Arkansas and Louisiana passed such laws only to have them struck down in state courts. The Louisiana law was then appealed all the way to the U.S. Supreme Court, which decided in 1987 (*Edwards v. Aquillard*) that because creationism is essentially a religious idea, teaching it in the public schools was a violation of the first amendment. Two justices, however, formally wrote that it would still be acceptable for teachers to present alternative theories to evolution (Scott 1994).

One response from opponents of evolution has been to drop the words creation and creator from their literature and call either for equal time for teaching that no evolution has occurred, or for teaching a proposal called Intelligent Design Theory, which infers the presence of a designer from the perfection of adaptation in contemporary organisms (Scott 1994; Schmidt 1996). In the fall of 2005 the case of *Kitzmiller et al. v. Dover Area School District* was tried in Dover, Pennsylvania. The school district had enacted a policy requiring that students in biology classes "be made aware of gaps/problems in Darwin's Theory and of other theories of evolution including, but not limited to, intelligent design." A group of parents sued the school district on the grounds, again, that the policy violates the first ammendment. The court agreed (Goodstein 2005; Jones 2005).

The complexity and perfection of organisms is a time-worn objection to evolution by natural selection. Darwin was aware of it; in his *Origin* he devoted a section of the chapter titled "Difficulties on Theory" to "Organs of extreme perfection." How can natural selection, by sorting random changes in the genome, produce elaborate and integrated traits like the vertebrate eye?

Perfection and Complexity in Nature

The English cleric William Paley, writing in 1802, promoted the Theory of Special Creation with a now-classic argument. If a person found a watch and discovered that it was an especially complex and accurate instrument, they would naturally infer that it had been made by a highly skilled watchmaker. Paley then drew a parallel between the watch and the perfection of the vertebrate eye and asked his readers to infer the existence of a purposeful and perfect Creator. He contended that organisms are so well-engineered that they have to be the work of a conscious designer. This logic, still used by creationists today, is called the Argument from Design (Dawkins 1986).

The Argument from Design contends that adaptations must result from the actions of a conscious entity.

Because we perceive perfection and complexity in the natural world, evolution by natural selection seems to defy credulity. There are actually two concerns here. The first is how random changes can lead to order. Mutations are chance events, so the generation of variation in a population is random. But the selection of those variants, or mutants, is nonrandom: It is directed in the sense of increasing fitness. And adaptations—structures or behaviors that increase fitness—are what we perceive as highly ordered, complex, or even perfect in the natural world. But there is nothing conscious or intelligent about the process. The biologist Richard Dawkins captured this point by referring to natural selection as a blind watchmaker.

A second, and closely related, concern is: How can complex, highly integrated structures, like the vertebrate eye, evolve through the Darwinian process of gradual accumulation of small changes? Each evolutionary step would have to increase the fitness of individuals in the population. Darwinism predicts that complex structures have evolved through a series of intermediate stages, or graded forms. Is this true? For example, when we consider a structure like the eye, do we find a diversity of forms, some of which are more complex than others?

The answer to these questions is yes. In some unicellular species there are actually subcellular organelles with functions analogous to the eye. The eyespots of a group of protozoans called euglenoids, for example, contain light-absorbing molecules that are shaded on one side by a patch of pigment. When these molecules absorb light, they undergo structural changes. Because light can reach them from one side only, a change in the light-absorbing molecule contains useful information about where light is coming from. Some dinoflagellates even have a subcellular, lenslike organelle that can concentrate light on a pigment cup. It is unlikely that these single-celled protists can form an image, however, because they are not capable of neural processing. Rather, their eye probably functions in transmitting information about the cell's depth in the water column, helping the cell orient itself and swim toward light.

More complex eyes have a basic unit called the photoreceptor. This is a cell that contains a pigment capable of absorbing light. The simplest type of multicellular eye, consisting of a few photoreceptor cells in a cup or cuplike arrangement, is shown in Figures 3.23a and 3.23b. This type of eye is found in a wide diversity of taxa, including flatworms, polychaetes (segmented worms in the phylum Annelida), some crustaceans (the shrimps, crabs, and allies), and some vertebrates. These organs are used in orientation and day-length monitoring (Willson 1984; Brusca and Brusca 1990). Slightly more complex eyes, like those illustrated in Figure 3.23c, have optic cups with a narrow aperture acting as a lens and may be capable of forming images in at least some species. These are found in a few nemerteans (ribbon worms) and annelids (segmented worms), copepod crustaceans, and abalone and nautiloids (members of the phylum Mollusca). The most complex eyes (Figure 3.23d) fall into two functional categories based on whether the photoreceptor cells are arrayed on a retina that is concave, like the eyes of vertebrates and octopuses, or convex, like the compound eyes of insects and other arthropods (Goldsmith 1990). These eyes have lenses, and in most cases are capable of forming images.

It is important to recognize that the simpler eyes we have just reviewed do not themselves represent intermediate forms on the way to more advanced structures. The eyespots, pigment cups, and optic cups found in living organisms are contemporary adaptations to the problem of sensing light. They are not ancestral forms. It is, however, sensible to argue that the types of eyes discussed here form an evolutionary pathway (Gould 1983, essay 1). That is, it is conceivable that eyes like these formed intermediate stages in the evolution of the complex eyes found in vertebrates, octopuses, and insects. This is exactly what Darwin argued in his section on organs of extreme perfection. (To learn more about the evolution of the eye, see Salvini-Plawen and Mayr 1977; Nilsson and Pelger 1994; Quiring et al. 1994; Dawkins 1994; Donner and Maas 2004; Gehring 2004; Fernald 2004.)
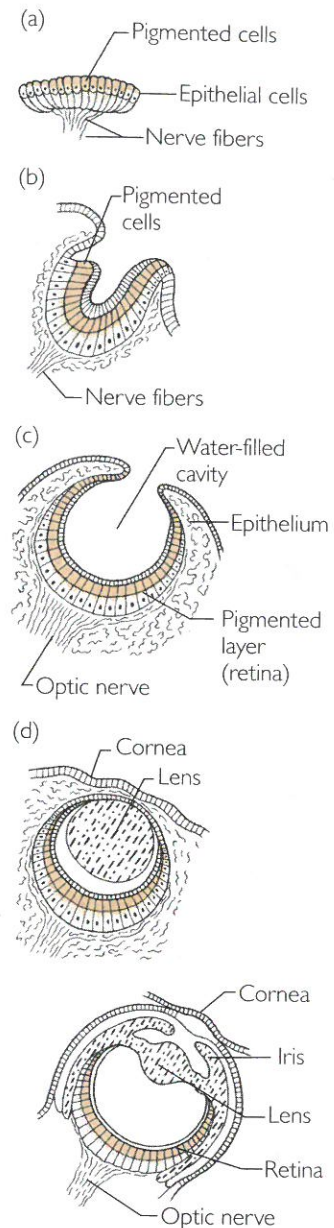

Figure 3.23 Variation in mollusc eyes (a) A pigment spot; (b) a simple pigment cup; (c) the simple optic cup found in abalone; (d) the complex lensed eyes of a marine snail called *Littorina* and the octopus. Pigmented cells are shown in color. From Brusca and Brusca 1990.

The Argument from Biochemical "Design"

Summarizing his views on perfection and complexity in nature, Darwin wrote (1859, p. 189):

> If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. But I can find out no such case.

Creationist Michael Behe (1996), believes he has found a profusion of such cases. Behe claims that many of the molecular machines found inside cells are irreducibly complex, and could not have been built by natural selection. Behe writes (p. 39):

> By *irreducibly complex* I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning.

Among the examples Behe offers is the eukaryotic cilium (also known, when it is long, as a flagellum).

Figures 3.24a and 3.24b show a cross section of the stalk, or axoneme, of one of these cellular appendages. Its main structural components are microtubules, made of proteins called α-tubulin and β-tubulin. At the core of the axoneme are two singlet microtubules, held together by a protein bridge. Surrounding the central pair are nine doublet microtubules. The doublet microtubules are connected to the central pair by protein spokes. Neighboring doublets are also connected to each other by an elastic protein called nexin. The cilium is powered by the dynein motors on the doublet microtubules. As the motors on each doublet crawl up their neighboring doublet, they cause the entire axoneme to bend.

Here is Behe again (1998):

> Cilia are composed of at least a half dozen proteins: alpha-tubulin, beta-tubulin, dynein, nexin, spoke protein, and a central bridge protein. These combine to perform one task, ciliary motion, and all of these proteins must be present for the cilium to function. If the tubulins are absent, then there are no filaments to
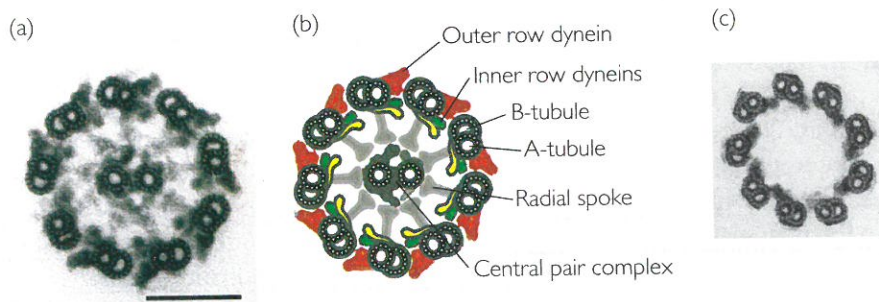
(a)   (b)   (c)

- Outer row dynein
- Inner row dyneins
- B-tubule
- A-tubule
- Radial spoke
- Central pair complex

Figure 3.24   Eukaryotic flagella (a) An electron micrograph showing a cross section through a flagellum of the single-celled alga *Chlamydomonas*. Scale bar = 100 nm (b) An interpretive drawing showing the individual components of the flagellum in (a). (c) A cross section through the flagellum of an eel sperm. See text for explanation. Parts (a) and (b) are from Mitchell (2000); (c) is from Woolley (1997).

slide; if the dynein is missing, then the cilium remains rigid and motionless; if nexin or the other connecting proteins are missing, then the axoneme falls apart when the filaments slide.

Behe finds it implausible that the cilium could have arisen by natural selection, a stepwise process in which each step involves an incremental improvement over what came before:

> [S]ince the complexity of the cilium is irreducible, then it can not have functional precursors. Since the irreducibly complex cilium can not have functional precursors it can not be produced by natural selection, which requires a continuum of function to work. Natural selection is powerless when there is no function to select.

Once he has concluded that the cilium cannot have arisen by natural selection, Behe infers that it must have been designed.

Intelligent Design Theory is a modern version of the Argument from Design.

The first thing we can say about Behe's argument is that the eukaryotic cilium is not, in fact, irreducibly complex. It is certainly not irreducibly complex in an evolutionary sense. This is demonstrated by organisms with cilia that are simpler in structure than the one pictured in Figure 3.24a and (b) (see Miller 1999). Figure 3.24c, for example, shows a cross section of an eel sperm's flagellum. It is fully functional, even though it lacks the central pair of singlet microtubules, the spokes, and the outer row of dynein motors. The cilium is not even irreducibly complex in a mechanical sense. This is shown by a mutation in the single-celled alga *Chlamydomonas* known as *pf14*. The flagella of cells carrying this mutation lack spokes. Although the *pf* in *pf14* stands for paralyzed flagella, the flagella of mutant cells do still function under the right chemical conditions or on the right genetic backgrounds (Frey et al. 1997).

The second thing we can say about Behe's argument is that even if the cilium were irreducibly complex, he would still be wrong to conclude that it cannot have functional precursors and cannot have been built by natural selection. Behe's argument assumes that evolution by natural selection builds molecular machines and their components from scratch, and that the individual component proteins are useless until the entire structure has been assembled in its final form. In fact, evolution by natural selection cobbles molecular machines together from preexisting and functional component proteins that it co-opts for new roles (True and Carrol 2002). If the components of complex molecular machines are recruited from other jobs, then we no longer have to explain how the components were maintained by selection while the machine evolved from scratch.

co-opt = ta in, absorbera, ta över

Richard Lenski and colleagues (2003) showed that evolution by natural selection can, in fact, build complex machines in just this way by studying populations of digital organisms. A digital organism is a self-replicating computer program. Each of the organisms in Lenski et al.'s virtual world has a genome composed of a series of simple instructions—low-level scraps of computer code. There are some two dozen possible instructions in all, which can be strung together in any order and repeated any number of times. Most possible sequences of instructions do nothing. Some allow an organism to copy itself. Still others allow an organism to take numbers as inputs, perform logical functions on them, and produce meaningful outputs. The researchers started with a large population of identical organisms whose modest-sized genomes allowed them to replicate themselves

but not to perform logical functions. Replication was imperfect, meaning that occasionally one or more of the instructions in the genome was replaced with another chosen at random, or an instruction was inserted or deleted at random. The organisms had to compete for the chance to run their instructions and reproduce. If an organism appeared that could correctly perform one or more logical functions, it was rewarded with additional running time.

The capacity to perform simple logical functions evolved first. Complex functions evolved later, building on the simple ones and co-opting them for new purposes. In genomes capable of performing the most complex function, many of the individual instructions were crucial; deleting them destroyed the organism's ability to perform the function. Intriguingly, some of the mutations on the path to the most complex function were initially harmful. That is, they disrupted the machinery for one or more simple functions. But they set the stage for later mutations that helped assemble new and more complex functions from old.

A striking demonstration of gene co-option in real organisms comes from the crystallins of animal eye lenses (True and Carrol 2002). Crystallins are water-soluble proteins that form densely packed, transparent, light-refracting arrays constituting about a third of the mass of the lens. Animal eyes contain an astonishing diversity of crystallins (Figure 3.25). Some, such as the α and $\beta\gamma$ crystallins, are widely distributed across the vertebrates and must have evolved early. These ancient crystallins evolved from duplicate copies of genes for proteins with other functions. Other crystallins are unique to particular taxa and must have evolved recently. Most of these recently evolved crystallins are similar or identical to enzymes that function outside the eye. Some, in fact, *are* enzymes that function outside the eye. That is, in some cases a single gene encodes a single protein that functions as an enzyme in some tissues and as a crystallin in the lens. The $\in$ crystallin in chickens, for instance, is a metabolic enzyme called lactate dehydrogenase B. The antifreeze proteins in the blood of Arctic and Antarctic marine fishes provide additional examples of proteins co-opted for new functions (Baardsnes and Davies 2001; Fletcher et al. 2001).

Crystallins and antifreeze proteins have simple jobs as proteins go. They have switched roles during their evolutionary history, but have not been incorporated into complex molecular machines. However, most of the components of the molecular machines Behe cites are homologous to proteins with other cellular functions. The microtubules and dyneins of the eukaryotic cilium, for example, are similar to components of the spindle apparatus employed in cell division. And work on simple examples such as crystallins and antifreeze proteins has paved the way for progress on more challenging problems. Researchers have begun reconstructing the evolutionary origins of complex molecular machines and metabolic pathways. Examples include the Krebs citric acid cycle (Meléndez-Hevia, et al. 1996; Huynen, et al. 1999), the cytochrome *c* oxidase proton pump (Musser and Chan 1998), the blood-clotting cascade (Krem and Di Cera 2002), and various bacterial flagella (Pallen and Matzke 2006).

Behe is right that we have not yet worked out in detail the evolutionary histories of the molecular machines he takes as examples of irreducible complexity. He would have us give up and attribute them all to miracles. But that is no way to make progress. Ironically, Behe began claiming that the origins of cellular biochemistry would never be deciphered just as the techniques and data required to do so were becoming available. Among these are automated DNA sequencers and the whole-genome sequences they are providing. We predict that in the coming decades all of Behe's examples of irreducible complexity will yield to evolutionary analysis.
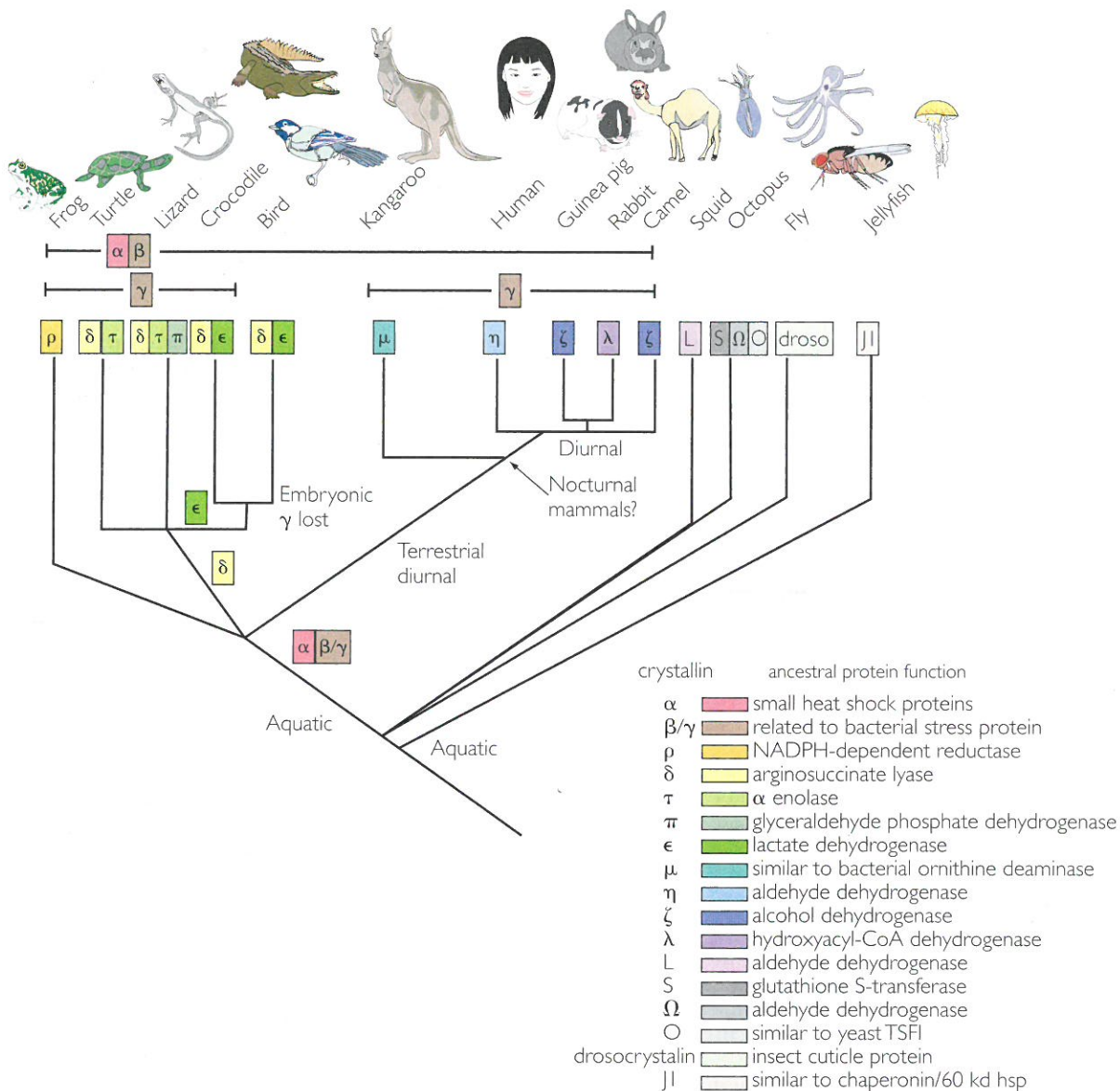
Figure 3.25 **Gene co-option in the crystallins of animal eye lenses** Crystallin proteins are major components of the lenses in animal eyes. All are derived from proteins with other functions. In some cases crystallins are encoded by duplicates of the genes for the proteins they are derived from; in other cases crystallins are encoded by the same genes. This phylogeny shows the evolutionary relationships among a variety of animals. The color-coded Greek letters indicate the crystallins found in the lenses of each animal. The table lists the proteins the various crystallins are derived from. Redrawn from True and Carroll 2002.

Other Objections

Here are four additional arguments that creationists use regularly, with responses from an evolutionary perspective (see Gish 1978; Kitcher 1982; Futuyma 1983; Gould 1983 essays 19, 20, 21; Dawkins 1986; Swinney 1994):

1. Evolution by natural selection is unscientific because it is not falsifiable and because it makes no testable predictions. Each of Darwin's four postulates is independently testable, so the theory meets the classical criterion that ideas must be falsifiable to be considered scientific. Also, the claim that evolutionary biologists do not make predictions is not true. Paleontologists routinely (and correctly) predict which strata will bear fossils of certain types (a spectacular example

was that fossil marsupial mammals would be found in Antarctica); Peter Grant and Rosemary Grant have used statistical techniques based on evolutionary theory to correctly predict the amount and direction of change in finch characteristics during selection events in the late 1980s and early 1990s (Grant and Grant 1993, 1995). Scientific creationism, on the other hand, amounts to an oxymoron; in the words of one of its leading advocates, Dr. Duane Gish (1978, p. 42): "We cannot discover by scientific investigations anything about the creative processes used by God."

2. Because Earth was created as little as 6,000–8,000 years ago, there has not been enough time for Darwinian evolution to produce the adaptation and diversity observed in living organisms. Creation scientists present short-Earth theories and argue that most geological landforms and strata resulted from the flood during the time of Noah. (For example, see Gish 1978 and Swinney 1994.) Most simply disbelieve the assumptions behind radiometric dating and deny the validity of the data. The assumption of uniformitarianism in the evolution of life and landforms is also rejected by creation scientists. Again, we quote Gish (1978, p. 42): "We do not know how God created, what processes He used, *for God used processes which are not now operating anywhere in the natural universe*" (emphasis original).

The assumptions of radiometric dating have been tested, however, and demonstrated to be correct. Radiometric dating has demonstrated that rock strata differ in age, and that Earth is about 4.6 billion years old.

3. Because organisms progress from simpler to more complex forms, evolution violates the Second Law of Thermodynamics. Although the Second Law has been stated in a variety of ways since its formulation in the late 19th century, the most general version is: "Natural processes tend to move toward a state of greater disorder" (Giancoli 1995). The Second Law is focused on the concept of entropy. This is a quantity that measures the state of disorder in a system. The Second Law, restated in terms of entropy, is "The entropy of an isolated system never decreases. It can only stay the same or increase" (Giancoli 1995).

The key to understanding the Second Law's relevance to evolution is the word "isolated." The Second Law is true only for closed systems. Organisms, however, live in an open system: Earth, where photosynthetic life-forms capture the radiant energy of the Sun and convert it to chemical energy that they and other organisms can use. Because energy is constantly being added to living systems, the Second Law does not apply to their evolution.

A similar objection is William Dembski's (2002) assertion that natural selection cannot lead the evolution of complex genetic information because it is no better than a random search. He stakes this claim on a set of results in theoretical computer science called the No Free Lunch Theorems. These show that averaged over all possible problems, no set of rules for finding a solution is better than any other, including random trial and error. But as Allen Orr (2002) points out, the No Free Lunch Theorems do not apply to Darwinian evolution, because Darwinian evolution is not a search for a predefined target. It is, instead, "sheer cold demographics." Genomes that make more copies of themselves become more common; genomes that make fewer copies disappear.

4. No one has ever seen a new species formed, so evolution is unproven. And because evolutionists say that speciation is too slow to be directly observed, evolution is unprovable and thus based on faith. Although speciation is a slow process, it is ongoing and can be studied. In Chapter 2 we discussed an example: Eastern versus western greenish warblers have diverged as they expanded their range around the Tibetan Plateau, to the

point that the two forms act like different species where they meet in the north. Chapter 16 will cover other experimental and observational studies of speciation in action.

Also, it is simply incorrect to claim that the only way to prove something happened is to observe it directly. Here is a rather contrived example: Imagine that you and two friends are stranded on an otherwise deserted island. You find one friend face down with a knife in his back, and you know that you did not do it. Although you did not directly observe the murder, you can infer the identity of the guilty party. We make inferences of this sort all the time in everyday life. They are common in science as well. We cannot observe atoms directly, for example, but there is considerable evidence on which to infer that they exist.

What Motivates the Controversy?

For decades, evolution by natural selection has been considered one of the best-documented and most successful theories in the biological sciences. Many scientists see no conflict between evolution and religious faith (Easterbrook 1997; Scott 1998), and many Christians agree. In 1996, for example, Pope John Paul II acknowledged that Darwinian evolution was a firmly established scientific result and stated that accepting Darwinism was compatible with traditional Christian understandings of God.

If the fact of evolution and the validity of natural selection are utterly uncontroversial, and if belief in evolution is compatible with belief in God, then why does the creationist debate continue?

During a discussion about whether material on evolution should be included in high school textbooks, a member of the Alabama State School Board named David Byers said, "It's foolish and naive to believe that what children are taught about who they are, how they got here, doesn't have anything to do with what they conclude about why they are here and what their obligations are, if, in fact, they have any obligations, and how they should live" (National Public Radio 1995). This statement suggests that, for some creationists, the controversy is not about the validity of the scientific evidence or its compatibility with religion. Instead, the concern is about what evolution means for human morality and behavior.

Creationists and evolutionists, it is safe to say, share the desire that children should grow up to become morally responsible adults. Creationists fight evolution because they believe it is morally dangerous. Evolutionary biologists, on the other hand, tend to believe that morality and moral guidance derive from sources outside of biology, and that children should learn what science shows us about how we and Earth's other living things came to be.

Summary

Before Darwin began to work on the origin of species, many scientists had become convinced that species change through time. The unique contribution made by Darwin and Wallace was to realize that the process of natural selection provided a mechanism for this pattern, which Darwin termed descent with modification.

Evolution by natural selection is the logical outcome of four facts: (1) Individuals vary in most or all traits; (2) some of this variation is genetically based and can be passed on to offspring; (3) more offspring are born than can survive to breed, and of those that do breed, some are more successful than others; and (4) the individuals that reproduce the most are a nonrandom, or more fit, subset of the general population. This selection process causes changes in the genetic makeup of populations over time, or evolution.