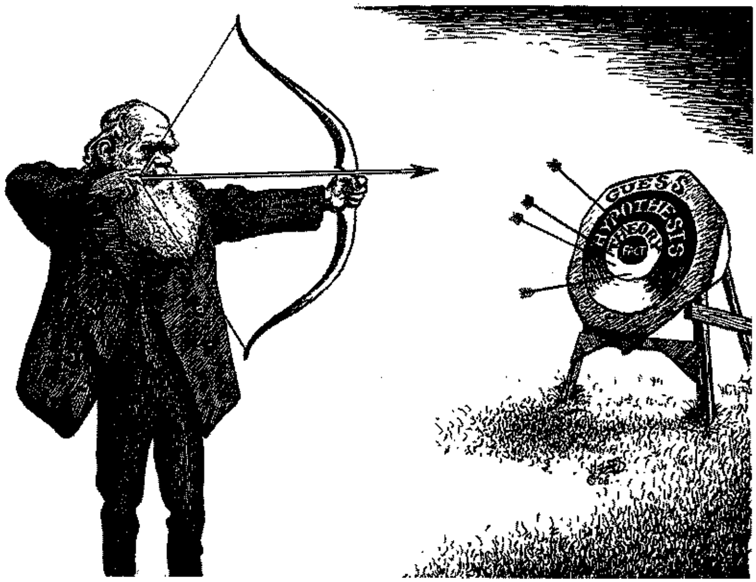

Myth Two

It's Just a Theory

Have you ever heard someone dismiss evolution by saying that it's just a theory? This view is so common in the United States that even many who accept evolution think of it as just a theory, as though it lacked scientific support. And some believe that if evolution is just a theory, then other "theories," namely, creationism, or its dressed-up twin, intelligent design, should be taught alongside evolution in public schools. In a number of American states, school boards have felt pressure to do just that. Where this has failed, some opponents of evolution have tried to require biology teachers to teach their students that evolution is just a theory.[1] In a recent attempt to dismiss evolution as just a theory, Georgia's Cobb County School District moved to put stickers on high school biology textbooks, stating that:

> This textbook contains material on evolution. Evolution is a theory, not a fact, regarding the origin of living things. This material should be approached with an open mind, studied carefully, and critically considered.

Who can dispute that all scientific work should be studied carefully and critically considered? And having an open mind is also an asset, but not so open that your brains fall out. Yet this is exactly what seems to have happened in Cobb County.[2]

The main problem with the textbook disclaimer has to do with two different meanings of the word *theory*.[3] In popular speech, *theory* means a guess or a hunch that can be just as good as any other guess or hunch, as when someone *theorizes* that a light streaking across the night sky must be an alien spacecraft. When scientists use the word *theory*, however, they're referring to "a logical, tested, well-supported explanation for a great variety of facts."[4] Scientific theories are not guesses.

Scientific disciplines don't all use identical methods, but they share a common approach. First, scientists will observe an object or a process (for example, Mars appears to travel backward in the sky about every twenty-six months, cholera rates are higher in poorer countries, there is a great diversity of species on Earth, and so on). They then formulate a question, asking how the object or the process works, or how it came to be. Then scientists try to answer the question in the form of an educated guess, a *hypothesis*. This hypothesis is tested by making a prediction and seeing whether the results of an experiment or further observation fit with the prediction. If the results don't fit, the hypothesis is either rejected, or it's modified and tested again. If the hypothesis eventually fits with the prediction, the scientists share this information—usually in a peer-reviewed journal —so that other scientists can test the hypothesis themselves.[5] Only

after a hypothesis repeatedly accounts for the facts or the observations can it then be considered a theory.

And even theories aren't etched in stone. They can be modified. Sometimes they can even be overthrown completely—as with the theories of *geocentrism* and *phlogiston*—but this requires very compelling evidence.[6] What makes the theory of evolution particularly powerful is that its supporting evidence comes from a wide array of individual scientific fields, including biology, botany, ecology, genetics, geology, paleontology, archaeology, embryology, and zoology.

Evolution is a legitimate scientific theory. It's well supported in the same way that the geological theory of plate tectonics supports and explains earthquakes, tsunamis, continental drift, and mountain formation. And it's as well supported as cosmological theories about how planets are formed or the age of our solar system. Some suggest that evolution is flawed because it can't be observed in the laboratory. It's true that evolutionary science doesn't rely as much on lab experiments as chemistry and physics do (although molecular biology and genetics are changing that), but neither do geologists, paleontologists, or other scientists who study historical processes. These historical sciences don't always apply the same methods as chemistry and physics. But we shouldn't expect them to, and we'd be foolish to dismiss them for it. Some complain that since evolution is concerned with the past, it can't make predictions because predictions are about the future. Thus, it's argued, evolution is not a legitimate scientific theory.

Odd as it may sound, predictions don't have to be about the future. Imagine that you're a molecular biologist, and you've observed that humans look more like chimpanzees than any other species. In light of evolution, this would suggest that we not only share a common ancestor with chimps, but also that our common ancestor may be more recent than any we share with other living animals. You know that the more closely related two individuals are, the more they have in common genetically, just as we're genetically more like our first cousins than our second cousins. So you can make a prediction (a hypothesis) that we have more in common genetically with chimps than with any other living species. If this is true, it will definitely support your hypothesis. Indeed, after studying the DNA, your prediction turns out to be correct.[7] Over 95 percent of our DNA is identical to chimpanzee DNA.[8] As a molecular biologist, you would also know that you can tell roughly how far back in time two individuals share a common ancestor by the differences in their DNA.[9] In the case of humans and chimpanzees, that shared ancestor lived between five and six million years ago.

Evolutionary theory also tells us that because species can change drastically over long periods of time, life in the past was different from life today. We can make a prediction that the further back in time we look, the greater the differences will be between older life-forms and modern life-forms. This turns out to be the case. Recent fossils resemble modern life-forms more than older fossils do.

So, predictions *can* be made about the past, and the results of these historical experiments provide compelling evidence supporting evolution. But as we'll see, earlier explanations for the Earth's great variety of life have been forced aside because they're not as well supported as modern evolutionary theory.

Lamarckism

About fifty years before Charles Darwin (1809–1882) published *On the Origin of Species*, a view of evolution we now call *Lamarckism* was proposed by the French naturalist Jean-Baptiste Lamarck (1744–1829). Lamarck was unique for his time in that he tried to apply strictly scientific explanations to the workings of the natural world. Darwin acknowledged Lamarck's scientific approach when he wrote, "He first did the eminent service of arousing attention to the probability of all change in the organic, as well as in the inorganic world, being the result of law, and not of miraculous interposition."[10] Unfortunately, Lamarck's ideas never became popular during his lifetime, and he died blind and in poverty. He was even buried in a rented

grave, and after five years his remains were removed and have been lost ever since. Although Lamarck's explanations weren't completely original,[11] he held a number of views that are now rejected by modern evolutionary theory, also called *neo-Darwinism*.[12] Since many people confuse Lamarckism with neo-Darwinism, it's important to understand how they're different.

Lamarck proposed two principles for how evolution works that are no longer supported by the evidence. One is the law of *use and disuse*. The other is the law of *the inheritance of acquired characteristics*.[13] The first law states that the more you use an organ or body part in making your living, the larger and stronger that part will become. The less you use that body part, the smaller and weaker it will become, eventually withering away if not used at all.

The first law makes sense when we're talking about muscles, which become larger the more they're used, and can atrophy if not used at all. But this isn't the case with many other body parts, such as sense organs. Your hearing does not become better the more you use your ears. And the same goes for using your eyes (although you can strengthen the muscles around your eyes by moving your eyeballs, this won't help with nearsightedness or farsightedness despite the claims of those peddling eye exercise kits).

The second law—*the inheritance of acquired characteristics*—states that the characteristics of stronger or weaker body parts acquired during your lifetime will be passed on through reproduction to your offspring. In other words, if you're a hardworking blacksmith, you'll develop strong muscles, and then your children will be born with larger-than-normal muscles because of your activity. If your children are also blacksmiths, they'll pass on even larger and stronger muscles to their children, and onward through the generations.

Lamarck's best-known example of acquired characteristics involves the evolution of the long necks of giraffes. Lamarck speculated that the ancestors of giraffes had shorter necks, and they would stretch their necks to reach high leaves in trees. Their descendants then inherited longer necks because of the stretching of the parents' necks. Lamarck thought that these changes in offspring could lead to a new species in just a few generations.

Unfortunately for Lamarckism, there's no evidence that acquired characteristics are passed on.[14] Lamarckism seems intuitively obvious, but today we know that alterations in our bodies acquired during our lifetime, such as larger muscles or stretched necks, are not encoded in our genes, and so they're not passed on to the next generation. Lamarck's ideas were reasonable for their time, but they turned out to be wrong. His ideas have been replaced by modern evolutionary theory, which better explains how characteristics are transmitted through inheritance, and how new characteristics arise.

What Evolution Is

Darwin described evolution as "descent with modification." This simply means changes in the properties of organisms over generations. These changes are explained by at least three independent processes that when taken together form what we mean by evolution.[15] These are *replication*, *variation*, and *selection*, and they are all observable facts. Replication is simply reproduction. Variation is genetic differences between parents and their offspring. And selection refers to natural selection, the process whereby those best adapted to their environment tend to survive and pass on their genes to the next generation.

Replication

Replication, or reproduction, can be either asexual or sexual. Asexual reproduction happens when offspring are created from a single parent without mixing in the genes from a second parent. These offspring are usually identical to that one parent, kind of like Xerox copies. They're natural clones. This form of reproduction is more common in plants than in animals, and it's also how bacteria reproduce. In contrast, sexual reproduction involves *combining* genes from two parents (male and female) to produce offspring. This is how most animals reproduce, as do many plants—through pollination.

Variation

Variation can arise in a number of ways. One of these is recombination. In sexual reproduction, recombination involves the "shuffling" of the various genes in the male and female sex cells (sperm and egg cells in animals) after these cells unite. This "shuffling," which occurs after conception, creates new gene combinations, making the offspring different from their parents. Another way for variation to arise is through mutation. Mutations are rare changes in the genes, which are often inherited. These changes usually occur as copying errors when cells multiply in the early stages of reproduction. Mutations can also be triggered by certain kinds of radiation, chemicals, and viruses. Many mutations are harmful, some are beneficial, but most seem to be neutral. Whether mutations are harmful, beneficial, or neutral may depend a lot on the environment.

Your body has natural defense systems that kill harmful bacteria. But some bacteria have developed mutations that give them resistance to your natural defenses, allowing them to thrive in their environment, that is, your body. In order to kill them, your bodily environment needs to change so that those mutations can no longer provide an advantage to the bacteria. This is where modern medicine comes in. If you had a serious bacterial infection, such as tuberculosis, your doctor would prescribe antibiotics designed to kill the TB bacteria. If you're fortunate, the bacteria will be killed. But bacteria reproduce rapidly—some as often as every twenty minutes. And often a few will have a mutation that provides resistance to a particular antibiotic. The mutation would be beneficial for the TB bacteria—but obviously not for you. Those antibiotic-resistant bacteria will reproduce, passing on their resistance to the next generation, at which point you would need a different (or stronger) antibiotic to kill the bacteria. And of course there may be some bacteria with a resistance to the new antibiotic, and then those mutant bacteria will come to dominate, and then you'll need a new antibiotic—assuming one has been developed—and on and on.[16] Some bacteria, such as TB, are highly infectious, and new resistant strains can spread easily. If an effective antibiotic has not yet been developed to fight these new strains, this could spell trouble. Doctors will tell you to finish the whole supply of antibiotics, even if you're feeling better, because hitting the bacteria with the prolonged, full dose will increase the chances of killing even those with a slight resistance.

Clearly, beneficial mutations play an important role in evolution since they're the ultimate source of genetic change. These variations arise randomly, in the sense that they don't look ahead and plan what will benefit the individual plant or animal.[17] They have no plan at all.

SELECTION

Natural selection is the great testing ground of variation. It's the mechanism that chooses which individuals will survive long enough to reproduce and transmit their genes to the next generation. Of course, natural selection doesn't choose intentionally. If a certain variation provides an advantage, then the individual with that variation stands a better chance of surviving. If it survives long enough to reproduce, it will transmit that beneficial variation to its offspring.

Consider the Komodo dragon, that giant reptile that can grow up to nine feet long and weigh over two hundred pounds. They populate three small islands in Indonesia, and they're rapacious hunters, with wild boars being one of their favorite foods. Imagine that a Komodo dragon is hiding in wait in the forest as a wild boar unwittingly approaches. Let's consider that this particular boar has been born with a slightly better sense of smell than his fellow boars. Now just before the Komodo dragon springs to ambush, the boar gets a

whiff of it, turns tail, and escapes to safety. Now imagine another boar that was not born with as good a sense of smell as our first boar. He doesn't sniff out the Komodo dragon, and gets pounced on, killed, and devoured by the Komodo, bones, hooves, and all. The boar born with the better sense of smell has an advantage over the other boar, and he stands a better chance of surviving long enough to procreate and pass on his genes for a sharper sense of smell to his offspring. After a period of time the genes for a sharper sense of smell will spread throughout the population because that boar, and others like him, are more likely to survive and reproduce.

The pressures affecting survival can sometimes be so great that the smallest beneficial variations can make a big difference. If a certain variation provides a disadvantage, such as a boar having a slightly worse sense of smell than its fellows, then that boar has a greater chance of becoming dinner for a predator before it has a chance to reproduce and pass on the genes for a slightly worse sense of smell.

It's important to understand that natural selection is not random. It doesn't allow just any variation to survive. In a sense natural selection is negative, in that it culls the herd. And this culling, whether in terms of pressure from predators, temperature changes in the environment, availability of food and water, and so on, will determine which variations survive. But natural selection is also positive in that it allows for variations to accumulate over time. Variations that provide for a slightly better sense of smell can arise many times, with each variation slightly sharpening that sense. Meanwhile, as the boars are evolving, so are the Komodo dragons. They may become faster, or develop better hearing, which makes them better at killing boars. After hundreds or thousands of generations of this escalating arms race, both Komodo dragons and wild boars will have changed significantly from their ancestors.

Another form of selection,[18] called *sexual selection*, can also play a role in the evolution of animals. Sexual selection involves members of one sex preferring certain characteristics in the opposite sex, and then choosing a mate based on which best displays those characteristics.

The peacock's tail feathers are an extreme example of sexual selection at work. Peahens (female peacocks) prefer peacocks with large, colorful tail feathers. The larger and the more colorful a peacock's tail feathers are, the greater his chances of being selected as a mate by a peahen. He will then pass on his genes for larger, colorful tail feathers to his offspring.

Sexual selection can be beneficial, although the selecting is not done with benefit in mind. It takes some energy for a peacock to parade around, displaying his large tail feathers during courtship. A healthier peacock has shinier feathers, and puts on a better show during his courtship display than a weaker or sickly peacock, whose feathers might be crawling with parasites and whose movements are less vigorous. So if the characteristics the female chooses (large, shiny feathers and vigorous displays) are also signs of good health, then the odds are greater that the offspring will be healthy. But the peahen is not thinking that by mating with a healthier peacock she will have healthier offspring. She just happens to be more attracted to peacocks with larger and shinier tail feathers and more vigorous displays. When she mates with one of these peacocks, the genes for large tail feathers will be expressed in her male offspring, and the genes for preferring larger tail feathers will be expressed in her female offspring.[19]

But sexual selection can also have its drawbacks since it still must pass the test of natural selection. Large and colorful tail feathers are great for attracting peahens, but they're also great for attracting predators since they're so visible from far away. Also, the tail feathers may require too much energy to fly with or to drag around, even when folded up. If a characteristic, such as large tail feathers, puts peacocks at great risk, then they might not live long enough to mate. In that case the peahens will have to settle for peacocks with smaller displays, which will then pass on their genes for smaller tail feathers.

Speciation

The processes just described—replication, variation, and selection—are occurring all the time in nature, and they're the key processes that collectively are called evolution. They are observable facts that no rational person can deny. Some who admit that these three processes exist still try to deny that evolution occurs. They make a distinction between microevolution (the changes that happen within a species) and macroevolution (the changes by which a new species evolves from an older species), and they deny macroevolution. But it's the same processes at work in both microevolution and macroevolution. The only difference is that macroevolution involves a longer timescale, and so allows many changes to accumulate. Accepting one but not the other is like declaring there are decades but not centuries or millennia.

One way for a new species to evolve is when some members of a species become geographically isolated from others. This can happen when a population of organisms extends its range, or when environmental changes break up the population. A number of things can cause geographical isolation, such as storms carrying birds, insects, or plant seeds to a distant habitat, or rising sea levels at the end of an ice age isolating separate populations of animals and plants on islands previously connected by land bridges. When a single population has been divided into two or more groups, new variations won't be shared by the two groups because they're isolated from each other. And if the environments have different food sources, weather, temperatures, soil conditions, predator and prey species, and so on, then different variations will be selected for by natural selection. Over a long period of time the two separate groups will become different enough from each other that if they were to come together, they wouldn't or couldn't interbreed, and they would be considered different species.

The length of time for a new species to arise can be considerable, and this is perhaps why it's so difficult for us to imagine macroevolution. It's easier to imagine if we look at species that diverged more recently and thus look similar, such as horses, donkeys, and zebras, which diverged about four million years ago. It may require a bit more imagination to conceive of the common ancestor of animals that diverged further back in time and look rather different now, such as whales and hippos. But DNA evidence suggests that hippos may be the closest living relatives to whales, with their most recent common ancestor traced back to about fifty-four million years ago.[20] It may be even harder to grasp that far enough back in time there existed a common ancestor of humans and horses, or even of humans and horseradishes. But all living things are related. You're certainly not a monkey's uncle (or aunt), but you're literally a monkey's cousin. We're all distant cousins, but some are more distant than others.

Disagreements within the Theory

Evolutionary biologists do sometimes disagree about which hypothesis better explains certain observations. But this doesn't mean that they reject the basic mechanisms of evolution—replication, variation, and selection—described above. There are parallels in other sciences. Geologists, for example, agree that the theory of plate tectonics best explains earthquakes and the movement of land masses. But not all agree on the mechanisms that drive the movement of the plates, especially as they relate to forces working very deep within the earth.[21] But we wouldn't suggest that geologists abandon plate tectonics because of disagreements about specific details. Plate tectonics is a relatively new theory, and it's in the process of being refined. Evolutionary biology is in a similar situation. There are disagreements about certain details, but not about the fact of evolution itself.

For example, one disagreement concerns how exactly to read the DNA clock that tells us how far back two individuals share a common ancestor.[22] These disagreements are being published and examined in peer-reviewed journals, and further research is being done to try to sort out these differences.[23] However, all of the debaters agree that evolution occurs.

Another disagreement concerns how humans became relatively hairless.[24] One hypothesis suggests that as our early human ancestors moved from the forests in central Africa to the hot, open savannah, hairlessness kept their bodies cooler, allowing them to forage for food for longer periods of time.[25] Another hypothesis holds that hairlessness provided an advantage against fleas and other biting parasites. Eventually freedom from parasites became a desirable trait in a mate, and hairlessness was a good way to advertise this.[26] Again, it's important to point out that there are disagreements over particular hypotheses within evolutionary science, yet these differences don't lead scientists to reject the theory of evolution. In fact, these hypotheses only make sense within the framework of evolutionary theory.

Science is inherently conservative, in that scientists don't usually embrace alternative explanations at the drop of a hat. They typically demand very convincing evidence before replacing one view with another. But when that evidence has been accumulated, scientific theories can be modified or even abandoned. The peer-review process helps keep science honest because it allows scientists to scrutinize one another's work and to test new hypotheses for themselves. It would take a lot of very convincing evidence to overturn the theory of evolution, and as things now stand, this convincing evidence is not to be found. There's no better explanation for Earth's great variety of life than the theory of evolution, and to dismiss it as "just a theory" is not only incorrect, it's also irresponsible.

Is Evolution Just a Theory?

We've seen that calling evolution "just a theory" involves a misunderstanding of what a scientific theory is. Evolution is a fact, and the three main processes that make up evolution—replication, variation, and selection—are observable and undeniable. While scientists do sometimes disagree about specific hypotheses within evolutionary theory, they don't reject the theory of evolution itself. Indeed, the theory of evolution does such a good job of explaining so many observations that the biologist T. Dobzhansky wrote, "Nothing in biology makes sense except in the light of evolution."[27]

Notes

1. M. Matsumura, "Tennessee Upset: 'Monkey Bill' Law Defeated," *NCSE Reports* 15, no. 4 (1995): 6–7; E. Scott, "State of Alabama Distorts Science, Evolution," *NCSE Reports* 15, no. 4 (1995): 10–11.

2. The attempt to place stickers on biology textbooks led to a lawsuit, *Selman v. Cobb County School District*. On January 13, 2005, a federal judge found the sticker policy unconstitutional.

3. Another problem with the textbook sticker incident is the ambiguous claim that evolution is a theory about the origin of living things. This could mean the origins of species by way of ancestral species—which is a fair description of what evolution is about—or this could mean the beginning of life on Earth. Although this second meaning is of interest to evolutionary science, it's hardly accurate to claim that this is what evolution is about.

4. National Center for Science Education, "What's Wrong with 'Theory Not Fact' Resolutions," National Center for Science Education, December 7, 2000, http://www.ncseweb.org/resources/articles/8643_whats_wrong_with_theory_not_12_7_2000.asp (accessed June 12, 2005).

5. Peer-reviewed journals are scholarly magazines where submitted articles are examined for accuracy by experts in a particular field before being published. In order to prevent bias, the reviewing is normally "blind," in that the reviewers are not told who has authored the articles.

6. *Geocentrism* is the theory that Earth is the center around which the sun and the planets revolve. This theory was replaced by *heliocentrism*, which has all the planets including Earth revolving around the sun. *Phlogiston theory* holds that all flammable materials contain an odorless, colorless, tasteless, weightless substance called *phlogiston,* which is given off during combustion. This theory was replaced by the "oxygen theory," which showed that oxygen is responsible for combustion.

7. DNA (deoxyribonucleic acid) is the molecule found in the nucleus

of cells that carries the instructions (or blueprints) for the growth and the development of most living organisms.

8. D. E. Wildman et al., "Implications of Natural Selection in Shaping 99.4% Nonsynonymous DNA Identity between Humans and Chimpanzees: Enlarging Genus *Homo*," *Proceedings of the National Academy of Sciences USA* 100 (2003): 7181–88.

9. The type of DNA used to estimate when the common ancestor of two species lived is *mitochondrial DNA*. Mitochondria are parts of cells that generate fuel for the activity of the cells, and they have their own DNA because (scientists believe) their ancestors were once separate organisms that became incorporated into plant and animal cells. Mitochondria are passed down only from the mother through reproduction, and their rate of change, or mutation rate, is slow and fairly predictable, making them excellent genetic clocks. See note 23.

10. C. Darwin, *The Origin of Species by Means of Natural Selection*, 6th ed. (London: Murray, 1872), p. xiv, http://pages.britishlibrary.net/charles.darwin/texts/origin_6th/origin6th_fm.html (accessed June 14, 2005).

11. For an insightful essay on how Lamarck is frequently misrepresented in history textbooks, see M. T. Ghiselin, "The Imaginary Lamarck: A Look at Bogus 'History' in Schoolbooks," *Textbook Letter*, September/October 1994, http://www.textbookleague.org/54marck.htm (accessed June 18, 2005).

12. Developed since the 1930s, neo-Darwinism (also called the *modern synthesis*) integrates Darwin's theory of natural selection with the theory of genetic inheritance first proposed by Gregor Mendel (1822–1884) and subsequently refined by later biologists. See E. Mayr and W. B. Provine, eds., *The Evolutionary Synthesis* (Cambridge, MA: Harvard University Press, 1980).

13. J. B. Lamarck, *Zoological Philosophy*, trans. H. Elliot (Chicago: University of Chicago Press, 1984), p. 113.

14. Because the field of genetics had not been developed in Darwin's time, he considered the inheritance of acquired characteristics a reasonable view. His hypothesis of *pangenesis* stated that certain traits acquired during the lifetime of an individual, such as large muscles, could be inherited by its offspring. His idea was that each part of the body produces tiny particles called *gemmules*, which enter into the reproductive organs, enabling them to be inherited by future offspring. Darwin acknowledged that his idea of pangenesis was pure speculation and that if it turned out to be mistaken, it

would not refute his position on natural selection. See C. Darwin, *The Variation of Animals and Plants under Domestication*, 2nd ed., vol. 2 (New York: Appleton, 1883), pp. 349–99, http://pages.britishlibrary.net/charles.darwin/texts/variation/variation_fm1.html (accessed June 20, 2005).

15. Other mechanisms affecting evolution include genetic drift and gene flow. For a concise explanation of these mechanisms, see E. Mayr, *What Evolution Is* (New York: Basic Books, 2001), pp. 98–99.

16. Many antibiotic-resistant strains of bacteria—known as *superbugs*—have evolved due to our overreliance on antibiotics, and they can pose a serious health risk.

17. R. Dawkins, *The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe without Design* (New York: Norton, 1986), p. 309.

18. Other types of selection not discussed here are artificial selection and kin selection.

19. Dawkins, *The Blind Watchmaker*, p. 203.

20. B. M. Ursing and U. Arnason, "Analyses of Mitochondrial Genomes Strongly Support a Hippopotamus-Whale Clade," *Proceedings of the Royal Society of London B* 265 (1998): 2251–55; M. Nikaido, A. P. Rooney, and N. Okada, "Phylogenetic Relationships among Cetartiodactyls Based on Insertions of Short and Long Interspersed Elements: Hippopotamuses Are the Closest Extant Relatives of Whales," *Proceedings of the National Academy of Sciences USA* 96 (1999): 10261–66.

21. W. J. Kious and R. I. Tilling, *The Dynamic Earth: The Story of Plate Tectonics* (Washington, DC: US Government Printing Office, 1996), pp. 53–55, http:// pubs.usgs.gov/publications/text/dynamic.pdf (accessed June 22, 2005).

22. See note 9.

23. For developing views on interpretation of the mitochondrial DNA clock, see A. Gibbons, "Calibrating the Mitochondrial Clock," *Science* 279, no. 5347 (1998): 28–29. See also R. Ota and D. Penny, "Estimating Changes in Mutational Mechanisms of Evolution," *Journal of Molecular Evolution* 57 (2003): S233–S240. See also S. Y. W. Ho et al., "Time Dependency of Molecular Rate Estimates and Systematic Overestimation of Recent Divergence Times," *Molecular Biology and Evolution* 22 (2005): 1561–68.

24. Of course humans are not truly hairless. The differences in the number of hair follicles between humans and other apes is not that significant. What makes human hair different is that it is short and fine.

25. P. E. Wheeler, "The Evolution of Bipedality and Loss of Functional Body Hair in Humans," *Journal of Human Evolution* 13 (1984): 91–98.

26. M. Pagel and W. Bodmer, "A Naked Ape Would Have Fewer Parasites," *Biology Letters* 270 (2003): S117–S119.

27. T. Dobzhansky, "Nothing in Biology Makes Sense Except in the Light of Evolution," *American Biology Teacher* 35 (1973): 125–29.