***Biological Science,* 3e**
Answers to Questions
Chapter 24: Evolution by Natural Selection

24.2 The Pattern of Evolution: Have Species Changed through Time?

Figure 24.4 Question How would these observations be explained under the theory of special creation?

ANSWER: The theory of special creation would explain that all species, including the fossil species, were created 6000 years ago, but that some species became extinct during the flood in Noah's time, described in the Bible. However, the theory of special creation cannot explain why the whale fossils are in such a perfect time sequence, nor can it explain the geographic patterns of similar fossils found on the same continent (i.e. the law of succession).

Figure 24.5 Question How would these observations be explained if evolution occurred via inheritance of acquired characters?

ANSWER: If these traits resulted from inheritance of acquired characteristics, some individuals must have acquired these traits during their own lifetimes. For example, a certain monkey's long tail might have been bitten off by a predator, or an ape's hair might have been pulled out of its skin by a rival during a fight. The new traits would then somehow have passed to the individuals' eggs and sperm, resulting in shorter-tailed and less-hairy offspring, until humans with a coccyx and goose bumps resulted.

Figure 24.6 Question How would these observations be explained under the theory of special creation?

ANSWER: The theory of special creation would explain that these species were created separately, as similar yet distinct forms, because God chose to create the species that way. Under special creation, there is no relationship among the four species, and they do not represent descendants of a common line. Special creation does not explain the noticeable similarities between the four species.

Figure 24.7 Question How would these observations be explained if evolution occurred via inheritance of acquired characters?

ANSWER: It is very difficult to come up with an explanation for how, during an animal's lifetime and through use, it could acquire a change in amino acid sequence. It is more difficult to explain why two organisms with such different eyes share 90 percent identity in a protein product responsible for eye location. Why should these proteins be similar at all on the amino acid level? Evolution via inheritance of acquired characteristics does not explain these observations well.

Figure 24.9 Question What is the relationship among genetic homologies, developmental homologies, and structural homologies?

ANSWER: Structural homologies are observed because developmental homologies exist; that is, a similar process of development produces similar adult structures. Genetic homologies underlie developmental and structural homologies; that is, similar genes direct development in such a way that similar adult structures are produced.

24.3 The Process of Evolution: How Does Natural Selection Work?

Figure 24.10 Question Why is it important that similar changes in allele frequencies have been observed in different populations of this species, independently?

ANSWER: A change in allele frequency in one population could be the result of genetic drift—pure chance, not natural selection. But if the pattern is seen independently in many populations, natural selection is the likely reason.

PracticeIt (page 491)
If you understand this concept, you should be able to make a table analogous to that in Figure 24.10c, illustrating what would happen to allele frequencies in the population if dark-barked trees were much more abundant than light-barked trees. You should also be able to explain what would happen if all of the variation in wing coloration were due to differences in nutrition or temperature that the individuals experienced—meaning that they all had the same genotype.

ANSWER:

	Frequency of light allele	**Frequency of dark allele**
Start	0.5	0.5
End	0.375	0.625

If all of the variation in wing coloration were due to differences in nutrition or temperature, then *natural selection could not occur*. Natural selection is based on variation in genotype, and if all of the individuals in a population have the same genotype, then there is no genetic variation. Any changes that individuals experienced would not be heritable and would not increase the fitness of the next generation. Individuals would still live or die according to their phenotype, but these events would not affect the next generation.

24.4 Evolution in Action: Recent Research on Natural Selection

Figure 24.11 Question In most individuals, the immune system is able to eliminate the few bacteria that remain at step 2. This individual had AIDS, however, so his immune system was compromised. Why did step 3 occur? If he had transmitted the infection to another person at step 3 or step 4, would they respond to drug therapy?

ANSWER: Step 3 occurred because the few bacteria remaining after drug therapy were not eliminated by the patient's weakened immune and thus were able to reproduce. If this individual had transmitted the infection to another person after step 3 or 4, most of the bacteria transmitted would have been resistant to drug treatment, so the newly infected individual would not have responded to drug therapy.

Figure 24.13 Question Why was the sample size so much smaller in 1978?

ANSWER: Many finches starved during the drought, so there were fewer birds to measure.

Figure 24.13 Exercise Fill in the predictions made by the two hypotheses.

ANSWER:

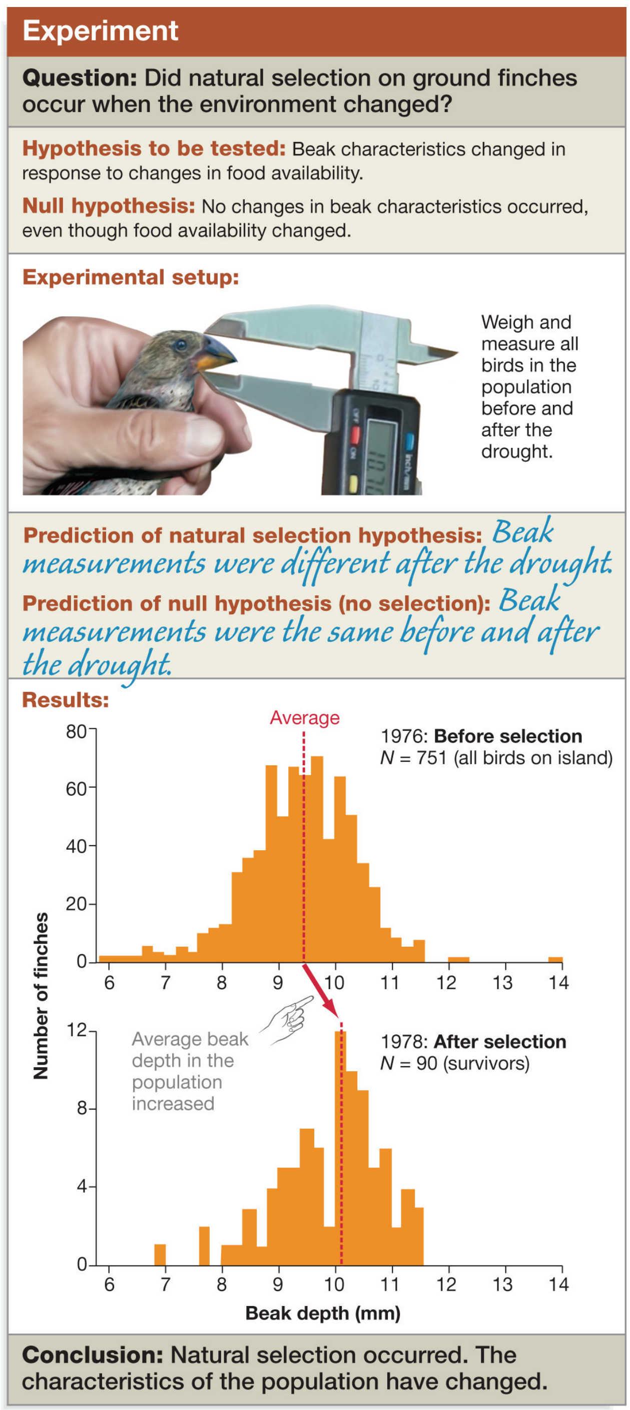


Figure 24.14 Exercise Label the drought in 1977 and the wet year in 1983. Circle years when (1) average body size increased, (2) average beak size declined, and (3) beaks became pointier.

ANSWER:

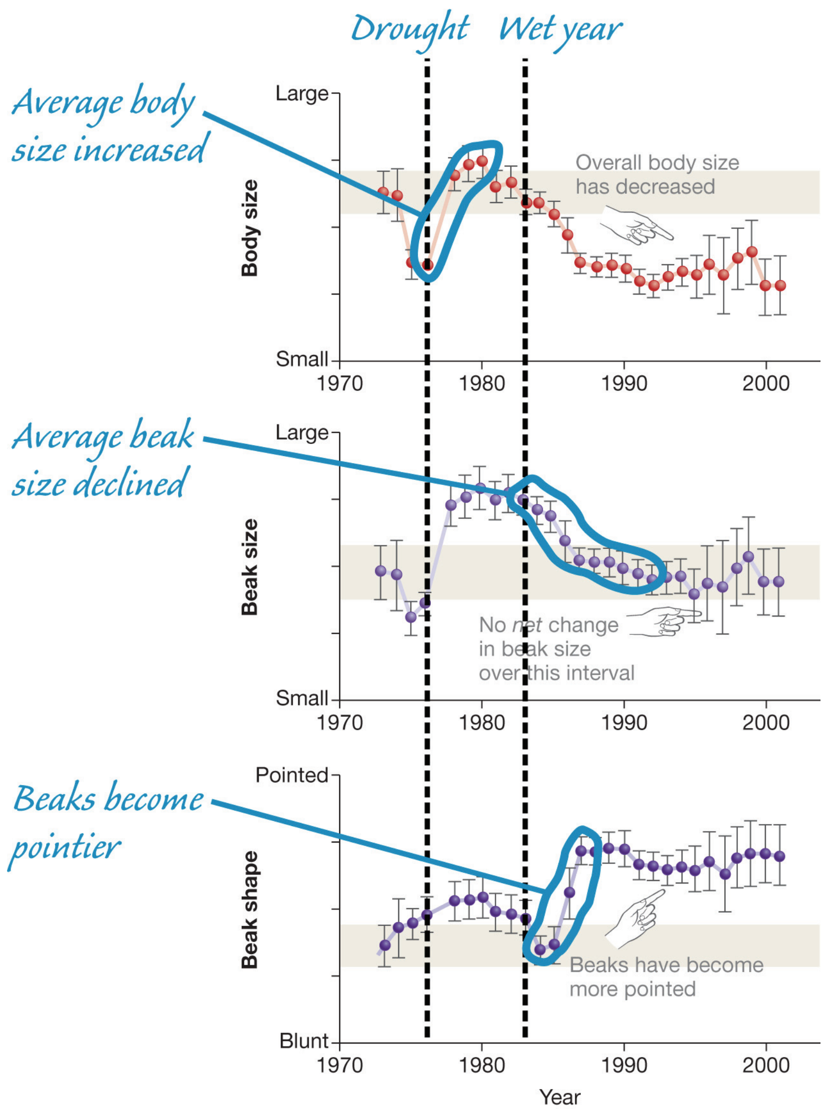
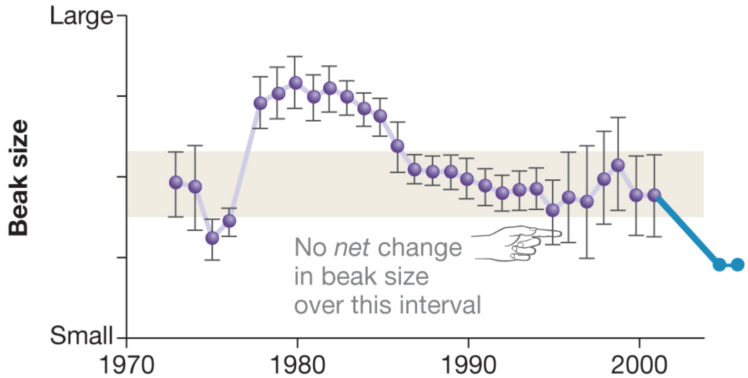


Figure 24.14 Exercise The Grants recently published more data on beak size (the middle graph). In 2005 and 2006, average beak size dropped to about the first hash mark above "Small" on the vertical axis. Place these data points on the graph. Do the new data change your interpretation?

ANSWER: The average beak size in 2005 and 2006 is somewhat below the mean range for the preceding 20 years, as shown in the figure below. However, this finding probably represents random variation and not a net change in beak size. Thus the interpretation remains that beak shape and body size have changed, but beak size has not.

ANSWER:



Check Your Understanding (page 495)

If you understand that . . .

- If individuals with certain alleles produce the most offspring in a population, then those alleles increase in frequency over time. Evolution—a change in allele frequencies—results from this process (natural selection on heritable variation).

You should be able to . . .

1) List Darwin's four postulates.

ANSWER: Darwin's four postulates concerning evolution by natural selection can be stated as follows: (1) Traits must vary within a population. (2) At least some of the trait variation must be heritable. (3) There must be variation in reproductive success; that is, some individuals produce more offspring than others. (4) Those individuals that have a particular set of heritable traits have the greatest reproductive success.

2) Relate the four postulates to heritable variation and differential reproductive success.

ANSWER: Evolution by natural selection occurs when heritable variation leads to differential survival and reproduction.

3) Illustrate heritable variation and differential reproductive success with an example drawn from research on natural selection in peppered moths, TB bacteria, and Galápagos finch populations.

ANSWER: Natural selection occurs when a change in the environment faced by a population selects for particular trait(s), as illustrated by these three examples:

• *Selection of wing color in peppered moths by bark color:* Moth populations exhibit heritable variation in wing color with some moths having gray wings and others having black wings. Black wing color is due to the presence of the dominant A_2 allele. In an environment where trees have light-colored bark, moths with black wings are more likely than those with gray wings to be eaten by birds and thus less likely to survive and reproduce. The opposite is true in an environment where trees have dark-colored bark. Over time, the frequency of the A_2 allele, which confers dark wing color, declines significantly in an environment with light-colored trees, as demonstrated in the experiment summarized in Figure 24.10.

• *Selection of the TB bacterium by drugs:* Any population of TB bacteria is likely to include individuals resistant to the drug rifampin, whereas most of the population are sensitive to rifampin. This resistance is due to a heritable mutation in the *rpoB* gene (i.e., the progeny of resistant bacteria also are resistant). In the absence of rifampin, TB bacteria with the *rpoB* mutation do not reproduce as successfully as the wild-type bacteria, so their frequency remains low. However, in tuberculosis patients treated with rifampin, most of the wild-type bacteria are killed while the mutant/resistant bacteria remain alive and reproduce. In time, the mutant/resistant bacteria come to predominate in the population, as illustrated in Figure 24.11.

• *Selection of beak size/shape in Galápagos finches by seed availability:* In the population of Galápagos finches studied by the Grants, some finches had large (deep), blunt beaks and some had small (narrow), pointed beaks. The variation in beak morphology was shown to be heritable; for example, finches with deep beaks tended to have offspring with deep beaks. After a severe drought began in 1977, a tough fruit became the primary food source. This fruit was largely ignored by the finches when other food sources were available. Only birds that had deep beaks could eat these tough fruits easily. Consequently, these finches were more reproductively successful than those with small beaks, and the average beak size in the population was greater during the next several years than before the drought. However, after annual rainfall returned to normal levels, there was an increase in fruits with small soft seeds. With this as the predominant food source, finches with narrow, long beaks were able to reproduce successfully. As a result, the average beak became more pointed and narrower over time, as shown in Figure 24.14. In the population of Galápagos finches, natural selection has occurred several times as the environment changed.

24.5 The Nature of Natural Selection and Adaptation

PracticeIt (page 496)
If you understand this concept, you should be able to explain the difference between the biological definition of adaptation and its use in everyday English, and then explain the difference between acclimation and adaptation.

ANSWER: In biology, an adaptation is any heritable trait that increases an individual's ability to produce offspring in a particular environment. In everyday English, adaptation often used to refer to an individual's nonheritable adjustment to meet an environmental challenge, a phenomenon that biologists call acclimation. The phenotypic changes resulting from acclimation are not passed on to offspring.

Figure 24.16 Question Why is the individual with the inner tube smiling?

ANSWER: The individual is smiling because he or she will survive and reproduce.

Check Your Understanding (page 500)
If you understand that . . .

- Selection by drugs on the TB bacterium and changes in seed availability to finches in the Galapagos are well-studied examples of evolution by natural selection.
- Evolution by natural selection is simple in concept but widely misunderstood.

You should be able to . . .

1) Explain why individuals do not change when natural selection occurs.

ANSWER: Even though natural selection acts on individuals, individuals do not change during natural selection. For example, an individual TB bacterium did not mutate and become rifampin resistant as a result of exposure to rifampin. Nor did the beak of a single finch get larger and stronger during the drought. Instead, those individuals that *already* possessed the adaptive trait survived or reproduced more often. As a result, the population changed over time.

2) Explain why evolution is not progressive.

ANSWER: Because evolution does not always lead to an increase in complexity or an improvement in the organism, it is not considered progressive. Indeed, traits can actually become simpler as a result of evolution by natural selection, as illustrated by the evolution of tapeworms. Although tapeworms presumably evolved from organisms with complex digestive tracts, they themselves lack one. Because tapeworms are parasites adapted to life within the digestive tract of a host, they are able to digest nutrients directly from the host.

3) Explain why trade-offs and genetic and historical constraints prevent adaptations from being "perfect."

ANSWER: Adaptation is not perfect because every adaptation has a trade-off. For example, having a large body allows a bird to win a fight over food resources. However, the extra body mass requires more food to sustain. Also, natural selection has to act on traits that already exist. This historical factor restrains natural selection so that it selects only for the best possible trait that already exists in a population, instead of creating the perfect trait for a given situation. Moreover, most organisms are genetically complex: The genes responsible for a certain trait often affect the phenotype of another trait. This genetic correlation means that if one trait is selected for in a population, another trait may also be inadvertently selected for, even if it is neutral or suboptimal with respect to adaptation.

Chapter Review PracticeIts (page 500 and 501)

You should be able to predict how changes in finch populations and *Mycobacterium* populations would be explained under the theory of special creation and under evolution by inheritance of acquired characters.

ANSWER: Under the theory of special creation, changes in finch populations and *Mycobacterium* populations would be explained as individual creative events governed by an intelligent creator. But the theory of special creation fails to explain the striking match between environmental challenges, existing genetic variation, and changes in subsequent generations. Under the theory of evolution by inheritance of acquired characters, these changes would be explained as changes that were experienced by individuals during their lifetime in response to environmental pressures and then were passed on to the next generation. For example, this theory would say that changes in the shape of finch beaks arose as individual finches ate different types of seeds, and then were passed on to the progeny of these finches. This theory does fairly well at explaining the changes that occur, but fails to explain how the changes could be inherited.

You should be able to explain the difference between the biological and everyday English definitions of the words *fitness* and *adaptation.*

ANSWER: In biology, fitness is the ability of an individual to produce offspring, relative to that ability in other individuals in the population. In everyday English, fitness is a physical attribute that is acquired as a result of practice or exercise. In biology, an adaptation is a heritable trait that increases an individual's ability to produce offspring in a particular environment. In everyday English, an individual's physiological adjustment to meet an environmental challenge is commonly referred to as an adaptation.

You should be able to give an example of an adaptation—such as the large brains of *Homo sapiens* or the ability of falcons to fly very fast—and discuss how it is constrained.

ANSWER: An example of an adaptation constrained by genetic correlation is the change in beak shape after the 1977 drought in the Galapagos Islands. Finches with deep beaks survived in greater numbers than finches with shallow beaks, and birds with narrow beaks survived in greater numbers than birds with wide beaks. These beak adaptations allowed the birds to eat the particular type of seeds that were left after the drought. However, birds with deep beaks also tend to have wide beaks. Therefore, the allele for wide beaks did not completely disappear in the population. For this reason, the inheritance of narrow beaks was constrained by the linkage of the wideness and deepness trait.

You should also be able to explain why self-sacrificing alleles cannot increase in frequency and why individuals do not change when selection acts on them.

ANSWER: Self-sacrificing alleles result in the death of the one carrying them. Therefore, they don't increase fitness, and natural selection will result in decreased frequency of these alleles. Individuals do not change when selection acts on them, because their adaptations are set from the moment of birth. Natural selection results in either an individual's survival and reproduction, or its death. Either way, the individual's genes do not change.

QUESTIONS

Answers to the Test Your Knowledge multiple-choice questions appear in the textbook.

Test Your Understanding (page 501)

1. Compare and contrast the theory of evolution by natural selection and the theory of special creation and evolution by inheritance of acquired characters. What are the central claims of each theory? What testable predictions does each make?

ANSWER: The central claim of the theory of evolution by natural selection is that genetic variation is the basis for adaptation, and that evolution proceeds automatically whenever this genetic variation results in differential reproductive success. When a population's environment changes, those individuals with the most adaptive traits for the new environment will survive and reproduce, passing on those traits. As a result, over long periods of time particular genetic traits accumulate in a population, eventually resulting in the formation of a new species. New species that arise in this way should do so in places geographically close to their ancestral species, and the fossil record should reflect this sequence of events. On the other hand, the theory of special creation says that all species present on earth today were created as we know them, are not related to other species, and are unable to change over time, and the fossil record should not have any particular sequence of fossils. Finally, the theory of acquired characters states that organisms can change during their lifetime and the changes that they acquire can be passed on to the next generation.

2. Some biologists encapsulate evolution by natural selection with the phrase "mutation proposes, selection disposes." Explain what they mean, using the formal terms introduced in this chapter.

ANSWER: The key to this phrase is to understand that mutation is always blindly producing new genetic variations, at random, without any forethought as to which variations might prove adaptive in the future. Natural selection then removes those mutations that are deleterious, and preserves the ones that are advantageous.

3. Review the section on the evolution of drug resistance in *Mycobacterium tuberculosis.*

- In *M. tuberculosis,* how does heritable variation arise for the trait of drug resistance?
- What evidence do researchers have that a drug-resistant strain evolved in the patient analyzed in their study, instead of having been transmitted from another infected individual?
- If the antibiotic rifampin were banned, would the mutant *rpoB* gene have lower or higher fitness in the new environment? Would strains carrying the mutation continue to increase in frequency in *M. tuberculosis* populations?

ANSWER: Heritable variation arises in *M. tuberculosis* by random mutation. The evidence that the drug-resistant strain was not transmitted from another infected individual is that the DNA sequence of the drug-resistant bacteria from the late infection was identical to the DNA sequence of the sensitive bacteria from the early infection, except for a single nucleotide change in the *rpo* gene. If rifampin had been banned, then the *rpoB* mutant strain would have had lower fitness in the environment, and it likely would not have continued to increase in frequency in *M. tuberculosis* populations.

4. Compare and contrast typological thinking with population thinking. Why was Darwin's emphasis on the importance of variation among individuals so crucial to his theory, and why was it a revolutionary idea in Western science?

ANSWER: Typological thinking is based on the idea that species are unchanging and that any differences between individuals within a species are unimportant. This type of thinking is found in the book of Genesis. In contrast, population thinking treats those differences —the variation among individuals—as a critical component of the nature of that species. Darwin's emphasis on the importance of variation was crucial to his theory because it is the differences among individuals that allow for adaptation and differential reproductive success in a changing environment. This type of thinking was revolutionary because it challenged the idea that species were unchanging.

5. The evidence supporting the pattern component of the theory of evolution can be criticized on the grounds that it is indirect. For example, no one has directly observed the formation of a vestigial trait over time. Due to the indirect nature of the evidence, it could be argued that structural and genetic homologies are coincidental and do not result from common ancestry. Is indirect evidence for a scientific theory legitimate? Are you persuaded that descent with modification is the best explanation available for the data reviewed in Section 24.2? Why or why not?

ANSWER: Indirect evidence is legitimate evidence for a scientific theory. In addition to evolutionary biology, other branches of science that rely on indirect observations of phenomena that cannot be observed directly include geology, astronomy, and particle physics. In the case of processes that occur over long periods of time, no one can observe them directly. However, indirect evidence can be gathered to see if predictions of the theory are met or not. For example, if a theory of evolution predicts that certain transitional fossils should be found in rocks of a certain age, then we can search in those rocks and see if those fossils are indeed found. (It was exactly this reasoning that led to the discovery of the fish-amphibian transitional fossils in the Devonian rocks of Greenland.) Thus, indirect evidence can stimulate further experimentation or analysis that can be used either to support or to refute the theory, depending on the outcome.

6. Why isn't evolution by natural selection progressive? Why don't the strongest individuals in a population always produce the most offspring?

ANSWER: Evolution by natural selection is not progressive, in that organisms do not necessarily become more complex over time. Natural selection is defined by a population's ability to adapt to its environment. Therefore, an organism may adapt to its environment by becoming simpler. The strongest or hardiest organisms do not necessarily produce the most offspring because they may not be the best adapted to the environment at that time.

Applying Concepts to New Situations (page 502)

1. The geneticist James Crow wrote that successful scientific theories have the following characteristics: (1) They explain otherwise puzzling observations; (2) they provide connections between otherwise disparate observations; (3) they make predictions that can be tested; and (4) they are heuristic, meaning that they open up new avenues of theory and experimentation. Crow added two other elements that he considered important on a personal, emotional level: (5) They should be elegant, in the sense of being simple and powerful; and (6) they should have an element of surprise.

How well does the theory of evolution by natural selection fulfill these six criteria? Think of a theory you've been introduced to in another science course—for example, the atomic theory or the germ theory of disease—and evaluate it by using this list.

ANSWER: The theory of evolution fits the six criteria as follows:

(1) It explains the puzzling observations of homologies, geographic proximities of similar species, law of succession in the fossil record, vestigial traits, and extinctions.
(2) It provides connections between the disparate ideas of genetic inheritance and the differential survival of organisms in a population in an environment.
(3) It makes predictions that can be tested—genetic similarity between organisms can be predicted by relatedness, and vice versa.
(4) It stimulates new areas of testing—for example, the genome project to understand the relatedness of all organisms, produce a tree of life, and look for answers to why different people respond in different ways to the same treatments or drugs.
(5) It is elegant, in that it is a simple idea that explains how the tremendous diversity of living organisms came about, what we see in the fossil record, and how changes in populations occur.
(6) It has an element of surprise, in that it completely altered scientific thinking and changed most people's ideas of the basic principles by which the world works.

2. The average height of humans has increased steadily for the past 100 years in industrialized nations. This trait has clearly changed over time. Most physicians and human geneticists believe that the change is due to better nutrition and a reduced incidence of disease. Has human height evolved?

ANSWER: Height increase in humans over the past 100 years is more likely due to environmental changes in health care that have enabled each person to more fully realize his or her height potential. There is no documented evidence that changes in the allele frequencies of the genes controlling height have occurred in the human population over the last 100 years, so there is no evidence of evolution.

3. Genome sequencing projects may dramatically affect how biologists analyze evolutionary changes in quantitative traits. For example, suppose that the genomes of many living humans are sequenced and that genomes could be sequenced from many people who lived 100 years ago. (That might be possible with preserved tissue.) If 20 genes have been shown to influence height, how could you use the sequence data from these genes to test the hypothesis that human height has evolved in response to natural selection?

ANSWER: Compare the sequences of the 20 genes from many samples of preserved human tissue with the sequences of the same genes from a large sample of currently living humans. If evolution has occurred, the frequency of alleles correlated with "tallness" should be significantly greater in living humans than in those who lived a hundred years ago.

4. In some human populations, individuals tan in response to exposure to sunlight. Tanning is an acclimation response to a short-term change in the environment. It is adaptive because it prevents sunburn. The ability to tan varies among individuals in these populations, however. Is the ability to tan an acclimation or an adaptation? Explain your logic.

ANSWER: The ability to tan is an adaptation because it is passed on from one generation to the next. The tan itself is not passed on, but the ability to tan is passed on; therefore it is heritable and can be classified as an adaptation.