How Populations Evolve 13

Charles Darwin made sense out of biology. He looked at what many others had seen and had an idea that no one had ever thought of—evolution through the mechanism of natural selection. This idea is as important to biology as the atom is to chemistry. Natural selection explains both the diversity of life and its adaptation to the environment. Copernicus and Galileo discovered where we fit in the universe. Einstein showed us our place in space and time. Darwin revealed our relationship to the living world. It all started on an ocean voyage, when Darwin was only 22 years old. This chapter starts with Darwin's voyage of discovery and explains where that voyage has since taken us in our understanding of life.

Organizing Your Knowledge

Exercise 1 (Module 13.1)

Web/CD Activity 13A *Darwin and the Galápagos Islands*
Web/CD Activity 13B *The voyage of the* Beagle: *Darwin's Trip Around the World*

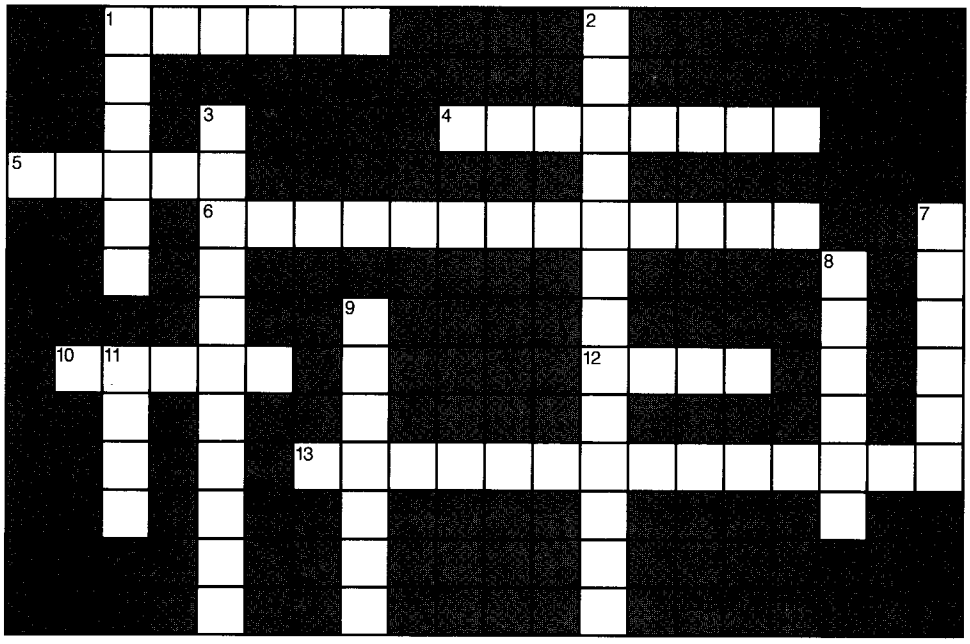
Charles Darwin was not the first person to ponder the origin of species. Match each of the following with his place in unraveling the history of life. Don't focus on names and dates, but rather on how ideas about the origin and history of life have changed over the centuries.

A. Darwin	_____ 1. Ancient Greek who believed living things have changed
B. Lyell	_____ 2. Greek philosopher who believed species to be fixed
C. Wallace	_____ 3. Fossils led this Frenchman to believe the Earth is old
D. Anaximander	_____ 4. Proposed that acquired characteristics are inherited
E. Aristotle	_____ 5. Believed in gradual geological change, not catastrophes
F. Lamarck	_____ 6. Wrote *The Origin of Species,* explaining "descent with modification"
G. Buffon	_____ 7. Conceived a theory of evolution identical to Darwin's

Exercise 2 (Modules 13.1 - 13.2)

Web/CD Activity 13B *The voyage of the* Beagle: *Darwin's Trip Around the World*

Review fossils by completing this crossword puzzle.



Across

1. Hard parts, such as bones, teeth, and ____, fossilize most easily.
4. A series of fossils shows how mammals evolved from ____.
5. Paleontologists recently found fossils of an ancient ____ with hind legs.
6. Sometimes a whole organism is preserved, if ____ does not occur.
10. Insects and other small animalsare often preserved in ____, fossilized tree resin.
12. An impression left by a seashell may fill with minerals to form a ____.
13. A ____ is a scientist who studies fossils.

Down

1. Layers of sedimentary rock are called ____.
2. ____ occurs when remains of dead organisms are turned to stone.
3. Fossils are usually found in ____ rocks.
7. The ____ fossils are found in the deepest strata.
8. A ____ is a preserved imprint or remnant of an ancient organism.
9. Some fossils retain ____ materials such as chlorophyll or proteins.
11. A seashell might make an imprint in mud, which forms a ____.

Exercise 3 (Modules 13.3)

In addition to fossils, there are other kinds of evidence for evolution. Name the category of evidence to which each of the following examples belongs.

Category	*Example*
_____	1. Fertilized eggs of earthworms, insects, and snails all go through the same pattern of cell division.
_____	2. The DNA of humans and chimpanzees is about 98% identical.
_____	3. Remains of upright-walking but small-brained apes have been found in Africa.
_____	4. All animals with backbones have 12 pairs of nerves extending from the brain.
_____	5. A protein called albumin is very similar in dogs and wolves, less similar in dogs and cats.
_____	6. The farther an island is from the mainland, the more different its plants and animals are from those on the mainland.
_____	7. Animals called trilobites were common in the oceans 300 million years ago, but they have been extinct for millions of years.

Exercise 4 (Modules 13.4 - 13.7)

Read these modules, and then review selection and population genetics by completing the following story.

If you think that the more you mow your lawn, the meaner the weeds get, you may be right. Researchers have found that in lawns that are mown regularly, the dandelions fight back! Of course, dandelions don't "know" what they are doing. But the dandelions in a regularly mown lawn reproduce faster than their ancestors in more "natural" environments.

[1]_____, the English scientist who first devised the theory of [2]_____, would have explained it this way: Not all dandelions are alike; they [3]_____ in color, size, and rate of maturation. Many of these characteristics are [4]_____, or passed on to offspring. Every dandelion flower is capable of producing hundreds, perhaps thousands, of white-tufted seeds in a season. This constitutes an [5]_____ of offspring, because [6]_____ are limited; not every dandelion seed will find just the right environment in which to grow. Darwin speculated that those individuals whose inherited characteristics [7]_____ them best to their environment would be more likely to [8]_____ and [9]_____ than less [10]_____ individuals. Their type would become more common in the next generation. Darwin called this phenomenon [11]_____. Many examples of natural selection are known, including the evolution of [12]_____ resistance in insects. Those whose genes protect them best from being poisoned leave more descendants. Resistant insects are seen in greater and greater numbers in succeeding generations. Less resistant individuals die out. Reproduction is central to natural selection; in fact, natural selection can be defined as [13]_____ success in reproduction.

Natural selection is at work when you mow the lawn. It might be helpful to discuss the dandelions in terms of [14]_____ genetics, the study of how genes affect population changes. The dandelions in your lawn make up a [15]_____, a group of individuals of the same species. The species is all dandelions, the group of populations whose individuals can interbreed. Depending on where you live, your lawn may be more or less [16]_____ from other dandelion populations. Through some quirk of nature, dandelions only reproduce asexually, even though they continue to produce nectar and pollen. So unlike most other flowers, dandelions in your lawn cannot cross-pollinate with other populations, although seeds may blow in from elsewhere, and seeds from your lawn might blow across town.

The characteristics of dandelions—color, height, shape of root system, and so on—are dictated by their genes. All the genes in the dandelion population make up the [17]_____. Apparently, the height of dandelions when they mature and produce seed and how long it takes to do this are controlled by genes, and these traits can vary from dandelion to dandelion. If you mow the lawn often enough, the slower-growing, taller dandelions get lopped off before they can produce any seeds. In terms of reproductive success, these dandelions are the less [18]_____ individuals in the population. Since they don't produce many offspring, this slow type will not be as numerous in the next generation, and their [19]_____ will make up a smaller proportion of the gene pool. On the other hand, dandelions that don't have to grow as tall or take as long to produce seed can reproduce between mowings. Their genes, and their fast-growing traits, will be better represented in the next generation. Such a small change in the frequencies of alleles in the gene pool is called [20]_____.

This story illustrates a familiar example of natural selection. Over time, the shorter, faster-growing dandelions will predominate in the lawn. Note that natural selection involves differences between individuals, but individual dandelions do not evolve. An individual does not change its growth rate. But because there is variation in the survival and reproduction of individuals with different characteristics, the [21]_____ of dandelions evolves.

Exercise 5 (Modules 13.8 – 13.9)

Imagine a population of 100 annual wildflowers, some red and some yellow. The red allele, *R*, is dominant; the yellow allele, *r*, is recessive. There are 36 *RR* plants in the population, 48 *Rr* plants, and 16 *rr* (yellow) plants. If the population is at Hardy-Weinberg equilibrium, what will be the frequencies of the various genotypes and the frequencies of the two alleles, *R* and *r*, in the next generation? Follow the example in Module 13.8 as a guide, and fill in the blanks below to figure out the frequencies for this example.

First, figure out genotype frequencies for the current generation:

A. Phenotypes	Red	Red	Yellow
B. Genotypes	____	____	____
C. Number of plants (total 100)	____	____	____
D. Genotype frequencies (number of genotypes/100)	____	____	____

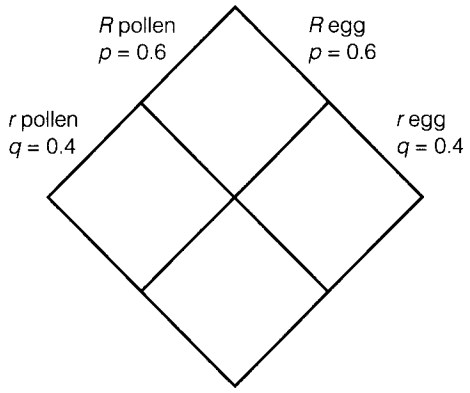
Next, figure out the frequencies of *R* and *r* alleles in the gene pool:

E. Number of *R* alleles in gene pool	____	____	____
F. Number of *r* alleles in gene pool	____	____	____
G. Allele frequencies (number of *R* alleles/200 or number of *r* alleles/200)	Frequency of *R*: p = ____		Frequency of *r*: q = ____

Now you know the frequency of *R* and *r* gametes these plants will produce:

H. Gamete frequencies (= allele frequencies)	Frequency of *R*: ____	Frequency of *r*: ____

Now you can use the rule of multiplication to calculate the frequencies of the three possible genotypes of plants in the second generation:



I. Phenotype	Red	Red	Yellow
J. Genotype	____	____	____
K. Genotype frequencies	____	____	____

Now you can figure out the frequencies of *R* and *r* alleles in the gene pool for the second generation (assuming the population stays at 100 individuals):

L. Number of *R* alleles in gene pool ____ ____ ____
M. Number of *r* alleles in gene pool ____ ____ ____
N. Allele frequencies
(number of *R* alleles/200
or number of *r* alleles/200) Frequency of *R*: p = ____ Frequency of *r*: q = ____
O. What happened to the genotype and allele frequencies in the second generation?

What would you predict for the third generation? Why?

Exercise 6 (Modules 13.10 - 13.12)

Web/CD Activity 13D *Cause of Microevolution*

The Hardy-Weinberg equilibrium is an idealized model. Equilibrium is maintained only if five conditions are met. This happens only in the fertile imaginations of biologists, not in real populations. Real populations always deviate from one or more of the conditions, and their gene pools change over time. The Hardy-Weinberg equilibrium is nevertheless a useful standard with which to compare real populations whose gene pools are changing.

Let's continue to look at the wildflower population introduced in Exercise 5. If it is like other real populations, its gene pool is changing. For each of the scenarios below, state which of the Hardy-Weinberg conditions the population deviates from, and explain what agent of microevolution causes the gene pool to change. Also state which of these deviations would cause the flowers to adapt to their environment.

1. A windstorm blows in hundreds of seeds from a nearby meadow, where nearly all the flowers are yellow.

2. A cosmic ray hits one of the red flowers just as a developing egg cell is replicating its DNA. Quite by chance, a red allele is transformed into a yellow allele.

3. The flowers tend to grow in red or yellow patches. A landslide buries and kills a huge patch of red flowers.

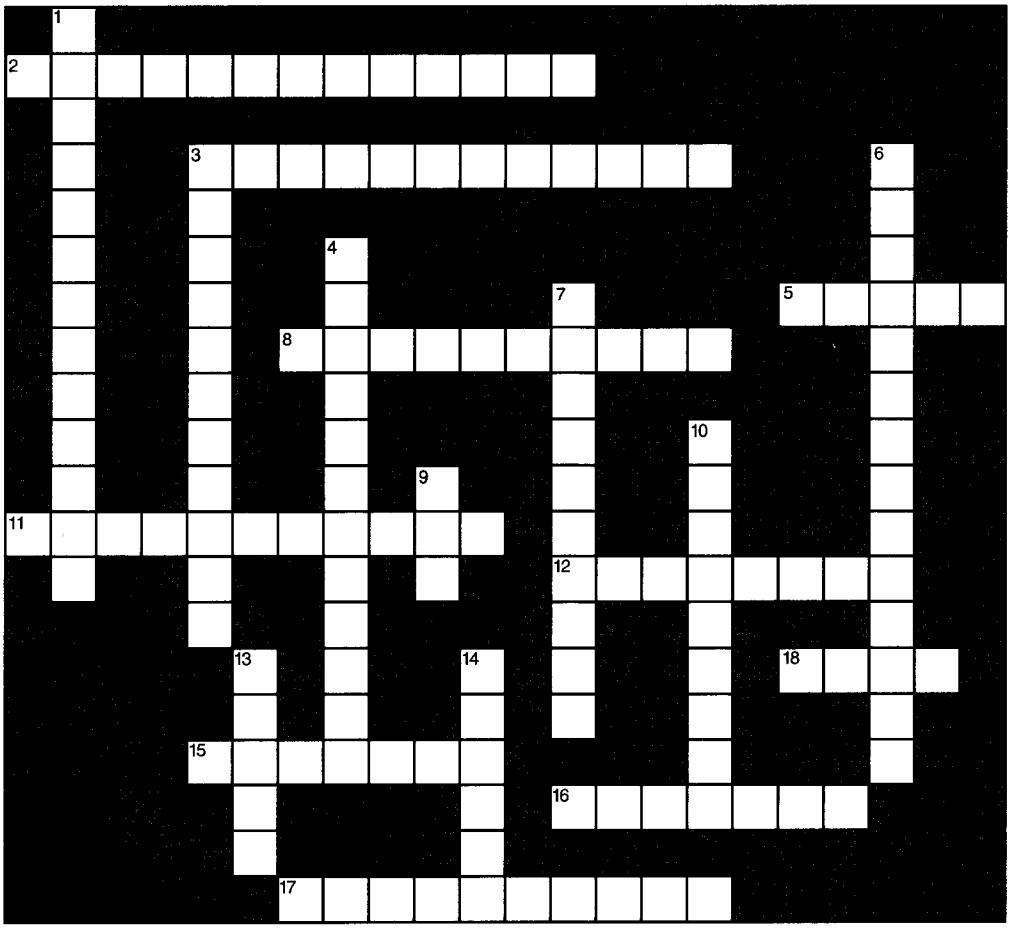
4. The red pigment in the petals of the red flowers is poisonous and tends to protect them from beetles that eat the developing seeds. The yellow flowers are not protected in this way.

5. The bees that pollinate the flowers tend to develop a "search image." Once they start visiting flowers of a certain color, they stick to that color. So pollen from red flowers is more likely to be delivered to other red flowers, and pollen from yellow flowers is more likely to fertilize other yellow flowers.

Exercise 7 (Modules 13.13 - 13.17)

Web/CD Activity 13E *Genetic Variation from Sexual Recombination*

Review the various terms and concepts relating to variation by completing this crossword puzzle.



Across

2. Mutation and sexual ____ generate variation.
3. Some characteristics controlled by several genes vary ____.
5. One form of a phenotypic characteristic is called a ____.
8. Cheetahs passed through a ____, which left them with reduced variation.
11. A population is ____ if two or more morphs are noticeably present.
12. ____ can create new alleles.
15. There are often many hidden recessive alleles in ____ organisms.
16. Only the ____ component of variation leads to adaptation.
17. ____ diversity is determined by comparing the base sequences of DNA samples.
18. Humans have much ___ genetic variation than most other species.

Down

1. Crossing over, independent assortment, and random ____ contribute to sexual recombination.
3. A ____ mutation is a large-scale change in a chromosome.
4. ____ variation occurs when the environment differs from place to place.
6. ____, which multiply rapidly, can quickly generate variation by means of mutation alone.
7. Endangered species such as cheetahs show extreme genetic ____.
9. ____ is a virus that mutates rapidly.
10. Heterozygote ____ means that heterozygotes do better than homozygotes.
13. A ____ is a gradual change in a characteristic along a geographical continuum.
14. Natural selection tends to ____ variation.

Exercise 8 (Modules 13.18 - 13.21)

Returning one last time to the wildflowers discussed in Exercises 5 and 6, complete the following scenario regarding fitness and natural selection.

An early writer on evolution described natural selection as "nature red in tooth and claw." This may be true for lions and zebras on the Serengeti, but natural selection is usually more subtle. All living things are engaged in what Charles Darwin called a [1]"_____ for existence." He called natural selection "survival of the [2]_____," but this involves more than brute strength. Biologists define Darwinian [3]_____ as the relative contribution that an individual makes to the gene pool of the next generation. It has more to do with reproduction than strength or cunning.

For the wildflowers in our previous example, the struggle for existence involves physical traits such as color and shape of leaves and metabolic characteristics like efficiency in capturing sunlight and resistance to cold. The [4]_____ of the plant is a composite of all its characteristics. Only the [5]_____, not the [6]_____, is exposed to the environment. A red flower may be protected from predation, while a yellow flower is eaten. Genes for red color increase fitness, and these genes are more likely to be passed on to the next generation. The frequency of red genes in the [7]_____ increases, as does the frequency of red individuals in the [8]_____. Of course, the fitness of an allele for a particular characteristic depends on its genetic [9]_____. A red flower with a weak stem that snaps easily in the wind might be less fit than a yellow flower with a stronger stem.

Most flowers contain both male and female parts, but because males and females are distinct in most animal species, natural selection often shapes differences in appearance, such as antlers or bright plumage. Such difference is called sexual [10]_____. Among some species, these [11]_____ sexual characteristics might be used in fighting over females. A more common form of sexual selection involves [12]_____ choice. Usually males display their bright "plumage" and females do the choosing.

There are three different ways in which natural selection can affect a population. Many characteristics are not simple "either/or" alternatives like red and yellow flower color. Characteristics like height vary continuously and can be described by a [13]_____-shaped curve: There may be a few very short plants in the population, a majority of plants of medium height, and a few very tall plants. Imagine our wildflowers growing in a cold, windy environment. Very tall plants might freeze before their seeds mature. Shorter plants would stay warmer, but very short plants might have trouble dispersing their seeds to favorable environments. In this kind of situation, [14]_____ selection favors the intermediate variants, not too tall and not too short. Next imagine a situation where the environment is gradually becoming drier. In this case, [15]_____ selection might favor those individuals genetically programmed to grow the deepest roots. This kind of natural selection is most common during periods of environmental [16]_____. Finally, [17]_____ selection occurs when two different sets of environmental conditions favor the extreme phenotypes and act against [16]_____ types. For example, plants with shallow, spreading roots might be at

an advantage in dry rocky soil, where water tends to penetrate quickly. At the same time, a deep taproot system might be favored in richer soil that holds water longer. Intermediate root systems would be at a disadvantage in both environments.

These examples are interesting, but does our understanding of fitness and natural selection have any practical application? As we have seen, natural selection explains insect resistance to insecticides and the resistance of bacteria to [19]_____.

Testing Your Knowledge

Multiple Choice

1. During his voyage around the world, Charles Darwin was inspired to think about evolution by
   a. books that he read.
   b. fossils he collected.
   c. studying adaptations of organisms to their environments.
   d. unique organisms he saw in the Galápagos Islands.
   e. all of the above.

2. _____ and _____ generate variation, while _____ results in adaptation to the environment.
   a. genetic drift . . . natural selection . . . mutation
   b. mutation . . . sexual recombination . . . natural selection
   c. overproduction of offspring . . . mutation . . . sexual recombination
   d. natural selection . . . mutation . . . sexual recombination
   e. sexual recombination . . . natural selection . . . mutation

3. Breeding of plants and animals by humans is called
   a. natural selection.
   b. sexual recombination.
   c. founder effect.
   d. artificial selection.
   e. neutral variation.

4. Microorganisms can adapt to changes in the environment by means of mutation alone because
   a. they are so small in size.
   b. their populations are very isolated from one another.
   c. a prokaryote is much more likely to mutate than a larger organism.
   d. they multiply so rapidly.
   e. their populations are so large.

5. The smallest unit that can evolve is a
   a. species.
   b. genotype.
   c. gene.
   d. population.
   e. morph.

6. "Differential reproduction" is just another way of saying
   a. natural selection.
   b. mutation.
   c. variation.
   d. recombination.
   e. genetic drift.

7. Which of the following changes in the gene pool results in adaptation to the environment?
   a. nonrandom mating
   b. genetic drift
   c. natural selection
   d. gene flow
   e. mutation

8. The ultimate source of all genetic variation is
   a. natural selection.
   b. genetic drift.
   c. sexual recombination.
   d. the environment.
   e. mutation.

9. In evolutionary terms, an organism's fitness is measured by its
   a. health.
   b. contribution to the gene pool of the next generation.
   c. mutation rate.
   d. genetic variability.
   e. stability in the face of environmental change.

10. Animals that possess homologous structures probably
    a. are headed for extinction.
    b. evolved from the same ancestor.
    c. have increased genetic diversity.
    d. by chance had similar mutations in the past.
    e. are not related.

11. Sexual recombination occurs when chromosomes are shuffled in _____ and fertilization.
    a. mitosis
    b. genetic drift
    c. natural selection
    d. mutation
    e. meiosis

12. Darwin
    a. was the first person to realize that organisms can evolve.
    b. believed that organisms could pass on acquired changes to offspring.
    c. was eager to publish his theory so that he could get all the credit.
    d. worked out the mechanism of evolution—natural selection.
    e. was the first to realize that fossils are remains of ancient organisms.

Essay

1. Explain how heritable variations, overproduction of offspring, and limited natural resources cause a species to adapt to its environment.
2. Briefly describe five categories of evidence for evolution.
3. What is the difference between a population and a species?
4. Horses look a lot like zebras. How would Darwin have explained this?
5. Sometimes a harmful allele may be present in the gene pool at a relatively high frequency. How might this be explained in terms of genetic drift? How might it relate to the fact that most organisms are diploid? What might it have to do with heterozygote advantage?
6. Describe how each of the following might alter the gene pool: genetic drift, nonrandom mating, gene flow, mutation, and natural selection.

Applying Your Knowledge

Multiple Choice

1. In a population of bears, which would be considered the fittest?
    a. the biggest bear
    b. the bear having the largest number of mutations
    c. the bear that blends in with its environment the best
    d. the strongest, fiercest bear
    e. the bear that leaves the most descendants

2. A geneticist mixed together many different kinds of fruit flies—some with long wings, some with short wings, some with red eyes, some with brown eyes, and so on. He allowed the flies to feed, mate randomly, and reproduce by the thousands. After many generations, most of the flies in the population had medium wings and red eyes, and most of the extreme types had disappeared. This experiment appears to demonstrate
    a. stabilizing selection.
    b. geographical variation.
    c. diversifying selection.
    d. genetic drift.
    e. fitness.

3. Rabbits living farther north tend to have smaller ears. This is an example of
    a. a cline.
    b. polymorphism.
    c. artificial selection.
    d. heterozygote advantage.
    e. genetic drift.

4. Blue poppies native to China are grown at a plant-breeding center in California, where those with the thickest leaves survive and reproduce best in the drier climate. This evolutionary adaptation of the poppies to their new environment is due to
    a. genetic drift.
    b. stabilizing selection.
    c. directional selection.
    d. neutral variation.
    e. diversifying selection.

5. Biologists have noticed that most human beings enjoy sex. How would they explain this, in evolutionary terms?
    a. If sex were not enjoyable, the human species would have died out.
    b. Early humans who enjoyed sex most had the most babies.
    c. Only body structures evolve, not behavior, so enjoyment cannot evolve.
    d. This was due to a random mutation, so it did not affect evolution.
    e. Like most people, biologists are baffled by the phenomenon of sex.

6. Which of the following would result in evolutionary adaptation of a mouse population to its environment?
   a. Half the mice are killed by an avalanche.
   b. A mutation for spotted fur occurs.
   c. Several mice leave the area and mate with individuals elsewhere.
   d. Mice with thicker fur best survive a cold winter.
   e. Mice are most likely to mate with close neighbors.

7. The relationship of genome to organism is the same as that of _____ to population.
   a. species
   b. gene
   c. gene pool
   d. mutation
   e. variation

8. Some critics of evolution believe that the theory of evolution is flawed because it is based on random changes—mutations. They say that a random change in an organism (or a car or a TV set) is likely to harm it, not make it function better. What logical statement could a defender of evolution make in reply to this criticism?
   a. Fossils prove without a doubt that mutations drive evolution.
   b. Mutation is random, but natural selection is not.
   c. Mutation has little to do with evolution.
   d. This is a weak spot in the theory that remains to be worked out.
   e. Mutations are not actually random.

9. A zoologist found that in the population of frogs in MacGregor's pond, half the genes for skin color in the gene pool were alleles for green spots, and half the genes were alleles for brown spots. Which of the following could cause these proportions to change?
   a. A drought shrinks the pond so that only five frogs remain.
   b. Brown-spotted females prefer to mate with brown-spotted males.
   c. Green-spotted frogs can hide more easily among the pond weeds.
   d. Filling in a nearby pond causes those frogs to move to MacGregor's pond.
   e. Any of the above could cause the proportions to change.

10. Each of us is part of the ongoing evolution of the human species. Which of the following occurrences would have the greatest impact on the future biological evolution of the human population?
    a. You work out every day so that you stay physically fit and healthy.
    b. A mutation occurs in one of your skin cells.
    c. You move to Hawaii, the state with the longest life expectancy.
    d. A mutation occurs in one of your sperm or egg cells.
    e. You encourage your children to develop their intellectual abilities.

11. We know a lot about fossil crabs, snails, and corals, but not much about ancient seaweeds. Why do you suppose this is the case?
    a. There were no seaweeds in ancient oceans.
    b. Seaweeds were too soft to fossilize well.
    c. Animal life was much more abundant than seaweeds in ancient times.
    d. Plants moved onto land, leaving only animals in the sea.
    e. A mass extinction wiped out the seaweeds, but animals survived.

Essay

1. A butterfly has a long tubelike proboscis that it uses to suck the nectar from a certain kind of deep, tubular flower. Its close relatives have much shorter proboscises. How might Lamarck have explained the existence of this long proboscis? How would Darwin have explained it?

2. A long section of *The Origin of Species* describes the breeding of pigeons and how pigeon breeders have produced many shapes, sizes, and colors of pigeons, all starting from a common wild pigeon. Why did Darwin think this was important?

3. Jeff and Trina collected some wildflower seeds from a meadow and scattered them along the roadside near their home. As the weather got hotter, some of the seedlings began to wither. Jeff said, "Hey, those scrawny plants are going to have to adapt or they are going to die." Trina replied, "*They* may not adapt, but the wildflower *population* might." What did she mean?

4. A population of 100 fish in an aquarium consists of 49 homozygous dominant green individuals, 42 heterozygous green individuals, and 9 white individuals. What are the frequencies of the three genotypes in the population? What are the frequencies of the green and white alleles in the gene pool? If the population is at Hardy-Weinberg equilibrium, what will the genotype and gene frequencies be in the next generation of fish?
5. Describe five ways in which the fish population in question 4 could be caused to deviate from Hardy-Weinberg equilibrium. Is this likely? Which of these deviations might cause the fish to become better adapted to their environment?
6. An ecologist studying predators and their prey in White Sand Dunes State Park found that nocturnal pocket mice exist in dark and light morphs. In this area, 42% of the mice are dark and 58% are light. Because owls swallow their prey whole and then cough up "pellets" consisting of bones and fur, the ecologist was able to discover that 61% of the mice caught by owls were dark, and 39% were light. What is likely to happen to the pocket mouse population in the future, and why?

Extending Your Knowledge

1. There is an ongoing controversy in the United States about the teaching of evolution in public schools. Proponents of "scientific creationism" and "intelligent design" demand equal time for explanations other than evolution by natural selection. Has this been an issue in your community or state? What evidence and arguments are presented by each side? How does each side answer the other's criticisms? Has your study of biology altered your opinions about this controvery? If so, in what ways?
2. Take a walk around your neighborhood, preferably in a natural area or park where living things are abundant. For each organism that you see, note an adaptation to its environment. How did the evolutionary processes discussed in this chapter shape the organism to fit its environment?