Exercise 4 (Modules 13.3–13.4)

In addition to fossils, examples of natural selection, and examples of artificial selection, there are other kinds of evidence for evolution: biogeography, comparative anatomy, and molecular biology. Each of the examples below illustrates which of these kinds of evidence?

Category	*Example*
_____	1. Fertilized eggs of earthworms, insects, and snails all go through the same pattern of cell division.
_____	2. The same gene seems to be involved in the formation of eyes in many animals.
_____	3. The genes of humans and chimpanzees are about 96% identical.
_____	4. Remains of upright-walking but small-brained apes have been found in Africa.
_____	5. All animals with backbones have 12 pairs of nerves extending from the brain.
_____	6. Bacteria quickly become resistant to antibiotics.
_____	7. The American Kennel Club recognizes more than 150 dog breeds.
_____	8. Many unique marsupial mammals live in Australia.
_____	9. A protein called albumin is very similar in dogs and wolves, less similar in dogs and cats.
_____	10. The farther an island is from the mainland, the more unique its plants and animals.
_____	11. The limbs of all land vertebrates have one upper "leg" bone and two lower "leg" bones.
_____	12. Humans have small tail bones, and occasionally a baby is born with a short tail.
_____	13. Animals called trilobites were common in the oceans 300 million years ago, but they have been extinct for millions of years.
_____	14. In all living things, AUG is the mRNA "start" codon.
_____	15. Some whales possess vestigial hind leg and foot bones.
_____	16. Cabbage, cauliflower, and broccoli were all bred from a wild mustard.

Exercise 5 (Modules 13.5–13.6)

A human arm and a bat wing are homologous structures—features that may have different functions but are structurally similar because of common ancestry. Such homologies, whether anatomical or molecular, are important clues to evolutionary relationships. Check off each of the examples in Exercise 4 (above) that illustrate homologous structures.

Exercise 6 (Modules 13.7–13.8)

These modules introduce evolution of populations. After reading the modules, circle the word that best matches each statement

1. A group of individuals of the same species: *gene pool, population*
2. What natural selection acts on: *individual, population*
3. What actually evolves: *individual, population*
4. All the alleles in all the individuals in the population: *genome, gene pool*
5. Change in relative frequencies of alleles in the gene pool: *microevolution, macroevolution*
6. Causes of variation (circle all that apply): *mutation, natural selection, sexual reproduction*
7. Portion of variation relevant to natural selection: *acquired, genetic*
8. Produces new alleles: *mutation, sexual reproduction*
9. Where most mutations occur: *body (somatic) cells, gametes*
10. Mutations that affect population's variability: *somatic mutations, mutations in gametes*
11. Most mutations: *harmful, helpful*
12. Important source of helpful variation: *deletion mutation, duplication mutation*
13. Organisms in which mutation alone generate most variation: *eukaryotes, prokaryotes*
14. Mutation rate in most plants and animals: *1/100,000, 1/1000*
15. Generates most new gene combinations in animals and plants: *mutation, sexual reproduction*
16. Sexual processes that generate variation: (circle all that apply) *crossing over, independent assortment, random fertilization*

Exercise 7 (Modules 13.9–13.10)

Microevolution is the change of frequencies of alleles in the gene pool. To see what happens when microevolution occurs, it is helpful to first look at a hypothetical population that is *not* evolving—a population at "Hardy-Weinberg equilibrium." 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 13.9 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)	____	____	____

chance. And because a plant must do many different things, adaptations are often
30 _____.

Test 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 reproduction . . . natural selection
   c. overproduction of offspring . . . mutation . . . sexual reproduction
   d. natural selection . . . mutation . . . sexual reproduction
   e. sexual reproduction . . . natural selection . . . mutation

3. Breeding of plants and animals by humans is called
   a. natural selection.
   b. balancing selection.
   c. founder effect.
   d. artificial selection.
   e. intersexual selection.

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. most of their mutations are helpful, rather than harmful.
   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. population.
   d. gene.
   e. individual.

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 adaptive evolution?
   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. Organisms 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. Recombination of alleles 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 conceive that organisms could change over time.
    b. believed that organisms could pass on acquired changes to offspring.
    c. was the first biologist to win the Nobel Prize.
    d. worked out the mechanism of evolution—natural selection.
    e. was the first to realize that fossils are remains of ancient organisms.
13. Endangered species are often subject to _____ which _____ genetic diversity.
    a. balancing selection . . . reduces
    b. the bottleneck effect . . . reduces
    c. disruptive selection . . . increases
    d. neutral variation . . . reduces
    e. genetic drift . . . increases

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. What are homologous structures? Give some examples. Why are homologous structures considered important evidence for evolution?
5. Horses look a lot like zebras. How would Darwin have explained this?
6. 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?
7. Describe how each of the following might alter the gene pool: genetic drift, nonrandom mating, gene flow, mutation, and natural selection.

Apply the Concepts

Multiple Choice

1. In a population of black bears, which would be considered the fittest?
   a. the biggest bear
   b. the bear having the most mutations
   c. the healthiest bear
   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. neutral variation.
   c. diversifying selection.
   d. genetic drift.
   e. fitness.
3. Because of global climate change, researchers have discovered that Arctic wildflowers are blooming weeks earlier than they did a few decades ago. The earlier blooming time seems to be genetic. This appears to be an example of
   a. directional selection.
   b. diversifying selection.
   c. bottleneck effect.
   d. sexual dimorphism.
   e. genetic drift.

4. From its first settlement in the 1700s and well into the 1900s, the island of Martha's Vineyard, Massachusetts, had a particularly high incidence of hereditary deafness. Off the island, about one person in 6,000 is deaf. In Chilmark, one of the villages on Martha's Vineyard, the incidence of deafness was one person out of 25! Which of the following is the most likely explanation for this high incidence of deafness?
   a. natural selection
   b. mutation
   c. founder effect
   d. heterozygote advantage
   e. sexual 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. The fossil record proves without a doubt that mutations drive evolution.
   b. Mutation is random, but natural selection has a nonrandom "sorting" effect.
   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. 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. The frequencies of dominant and recessive alleles in a gene pool are 0.2 and 0.8. If this population is at Hardy-Weinberg equilibrium, what is the frequency of heterozygotes in the population?
    a. 0.04
    b. 0.16
    c. 0.2
    d. 0.32
    e. 0.64

Review the Concepts

Work through the following exercises to review the concepts in this chapter. For additional review, check out the activities at www.mybiology.com. The website offers a pre-test that will help you plan your studies.

Exercise 1 (Modules 14.1–14.2)

There are several ways that biologists define a species. Several are listed below. Match each of the descriptions on the left with a species concept on the right.

_____ 1. The smallest group that shares a common ancestor; one branch on the tree of life
_____ 2. Body form; shape, size and other features; what the organism looks like
_____ 3. Populations whose members can interbreed in nature and produce fertile offspring.
_____ 4. Organisms with a particular niches or roles in the biological community.

A. Biological species concept
B. Ecological species concept
C. Phylogenetic species concept
D. Morphological species concept

Exercise 2 (Modules 14.2–14.3)

The biological species concept is one of the most useful ways to define a species, but it is not foolproof. Briefly explain why it might be difficult to apply the biological species concept in each of the following situations.

1. Fossils of "Java Man" and "Peking Man" are both thought to represent a single species—*Homo erectus*.

2. A tiger and a lion can interbreed in a zoo and produce a hybrid offspring called a tiglon.

3. Dogs come in many shapes and sizes, from Chihuahuas to Saint Bernards.

4. There are many strains and species of *Streptococcus* bacteria, which reproduce asexually.

5. Among *Clarkia* wildflowers in California, flowers of population A can interbreed and produce fertile offspring when crossed with flowers from population B. Similarly, B can interbreed with C. But A and C cannot successfully interbreed.

6. One bird guide calls flycatchers of the genus *Empidonax* "the bane of bird-watchers." Several species look so much alike that birders can distinguish them only by their songs.

7. A song sparrow population in Baja, California, is separated from other song sparrows by over a hundred miles of desert.

Exercise 3 (Module 14.3)

Review the reproductive barriers that separate species by categorizing the following examples. State whether each barrier is prezygotic (pre) or postzygotic (post), and then name the specific kind of barrier (such as temporal isolation or reduced hybrid viability) it exemplifies. Table 14.3 is a helpful summary.

	Pre or Post	*Kind of Barrier*	*Example*
1.	_____	_____	The salamanders *Ambystoma tigrinum* and *A. maculatum* breed in the same areas. *A. tigrinum* mates from late February through March. *A. maculatum* does not start mating until late March or early April.
2.	_____	_____	Two species of mice are mated in the lab and produce fertile hybrid offspring, but offspring of the hybrids are sterile.
3.	_____	_____	When fruit flies of two particular species are crossed in the lab, their offspring are unable to produce eggs and sperm.
4.	_____	_____	A zoologist observed two land snails of different species that were trying to mate with little success because they apparently did not "fit" each other.
5.	_____	_____	Male fiddler crabs (genus *Uca*) wave their large claws to attract the attention of females. Each species has a slightly different wave.
6.	_____	_____	When different species of tobacco plants are crossed in a greenhouse, the pollen tube usually bursts before the eggs are fertilized.
7.	_____	_____	Blackjack oak (*Quercus marilandica*) grows in dry woodlands, and scrub oak (*Q. ilicifolia*) grows in dry, rocky, open areas. Pollen of one species seldom pollinates the other.
8.	_____	_____	The tiglon offspring of a lion and a tiger are often weak and unhealthy.

Exercise 4 (Module 14.4)

Allopatric speciation often begins with geographical isolation. For each of the organisms listed below, name two geographical barriers that might block gene flow between populations and possibly lead to allopatric speciation.

1. Daisy
2. Mouse
3. Trout
4. Oak tree
5. Sparrow
6. Sea star

Test Your Knowledge

Multiple Choice

1. According to the biological species concept, two animals are considered different species if they
   a. look different.
   b. cannot interbreed.
   c. live in different habitats.
   d. are members of different populations.
   e. are geographically isolated.

2. Which of the following is the first step in allopatric speciation?
   a. genetic drift
   b. geographic isolation
   c. polyploidy
   d. hybridization
   e. formation of a reproductive barrier

3. Bacteriologists usually use the morphological species concept to define species because
   a. bacteria often hybridize.
   b. bacterial reproduce sexually.
   c. bacteria are so small.
   d. bacteria reproduce very rapidly.
   e. bacteria reproduce asexually.

4. A new species can arise in a single generation
   a. through geographic isolation.
   b. in a very large population that is spread over a large area.
   c. if a change in chromosome number creates a reproductive barrier.
   d. if allopatric speciation occurs.
   e. because of hybrid breakdown.

5. The evolution of numerous species, such as Darwin's finches, from a single ancestor is called
   a. adaptive radiation.
   b. sympatric speciation.
   c. punctuated equilibrium.
   d. polyploidy.
   e. geographic isolation.

6. According to the _____ model, evolution occurs in spurts; species evolve relatively rapidly, then remain unchanged for long periods.
   a. allopatric
   b. gradual
   c. adaptive radiation
   d. punctuated equilibrium
   e. geographic isolation

7. Most of the time, species are identified by their appearance. Why?
   a. If two organisms look alike, they must be the same species.
   b. This is the criterion used to define a biological species.
   c. If two organisms look different, they must be different species.
   d. This is the most convenient way of identifying species.
   e. Most organisms reproduce asexually.

8. Most species of _____ are descended from ancestors that underwent sympatric speciation by polyploidy.
   a. plants
   b. bacteria
   c. land mammals
   d. insects
   e. fish

9. Individuals of different species living in the same area may be prevented from interbreeding by responding to different mating dances. This is called
   a. ecological isolation.
   b. hybrid breakdown.
   c. mechanical isolation.
   d. temporal isolation.
   e. behavioral isolation.

10. It is unlikely that the human population will give rise to a new species because
    a. the human population is too large.
    b. geographic isolation is unlikely to occur.
    c. a change in chromosome number would be fatal.
    d. the human population is too diverse.
    e. natural selection cannot affect humans.

Essay

1. Give three situations in which it might be difficult to use the biological species concept to decide whether two organisms are of the same or different species.

2. Describe step-by-step how geographic isolation could lead to speciation.

3. Describe what has to happen for two species with different numbers of chromosomes to interbreed and produce a fertile hybrid. Will this hybrid be able to interbreed with either of its parents? Why? How common is this in nature?

4. State whether a large, widely distributed population or a small, isolated population is more likely to undergo speciation, and explain why.

5. Compare the gradual and the punctuated equilibrium models of species evolution. What would the fossil record of speciation look like if it supported the gradual model? What would it look like if punctuated equilibrium were the case? Which model does the fossil record seem to support most often? Why?

Apply the Concepts

Multiple Choice

1. Three species of frogs—*Rana pipiens, Rana clamitans,* and *Rana sylvatica*—all mate in the same ponds, but they pair off correctly because they have different calls. This illustrates a ____ and ____ .
   a. prezygotic barrier . . . behavioral isolation.
   b. postzygotic barrier . . . hybrid breakdown.
   c. prezygotic barrier . . . temporal isolation.
   d. postzygotic barrier . . . behavioral isolation.
   e. prezygotic barrier . . . gametic isolation.

2. Two closely related species of rabbits may occasionally mate, but their embryos are never viable. Which of the following is a possible consequence?
   a. hybridization
   b. reinforcement of reproductive barriers
   c. fusion of gene pools
   d. polyploidy
   e. a stable situation with gene flow between populations

3. Bullock's oriole and the Baltimore oriole are closely related, but are they the same species? To find out, you could see whether they
   a. sing similar songs.
   b. look alike.
   c. live in the same areas.
   d. have the same number of chromosomes.
   e. successfully interbreed.

4. Sometimes two quite different populations interbreed to a limited extent, so that it is difficult to say whether they are clearly separate species. This does not worry biologists much because it
   a. is quite rare.
   b. is true for almost every species.
   c. supports the theory of punctuated equilibrium.
   d. may illustrate the formation of new species in progress.
   e. happens only among plants, not among animals.

5. Two species of water lilies in the same pond do not interbreed because one blooms at night and the other during the day. The reproductive barrier between them is an example of
   a. temporal isolation.
   b. gametic isolation.
   c. mechanical isolation.
   d. hybrid breakdown.
   e. ecological isolation.

6. Comparison of fossils with living humans seems to show that there have been no significant physical changes in *Homo sapiens* in 30,000 to 50,000 years. What might an advocate of punctuated equilibrium say about this?
   a. It is about time for humans to undergo a burst of change.
   b. That is about how long we have been reproductively isolated.
   c. It is impossible to see major internal changes by looking at fossils.
   d. You would expect lots of changes in the skeleton in that time period.
   e. Lack of change is consistent with the punctuated equilibrium model.

7. Which of the following is an example of a postzygotic reproductive barrier?
   a. One species of frog mates in April; another mates in May.
   b. Two fruit flies of different species produce offspring that are sterile.
   c. The sperm of a marine worm only penetrate eggs of the same species.
   d. One species of flower grows in forested areas, another in meadows.
   e. Two pheasant species perform different courtship dances.

8. The Hawaiian Islands are home to more than twenty species of birds called honeycreepers, each with a slightly different diet and habits. All these birds probably evolved from one ancestor, an example of
   a. sympatric speciation.
   b. hybrid breakdown.
   c. adaptive radiation.
   d. gradualism.
   e. punctuated equilibrium.

9. A botanist found that a kind of white daisy had a diploid chromosome number of 16. In the same area, he found a yellowish daisy. Its cells contained 24 chromosomes. He found that the yellowish daisy was a polyploid descendant of the white daisies. Which of the following would