UNIT 5 Evolution

Kingfisher male with courtship gift

Insect of the newly named order Mantophasmatodea

UNIT 5

Poison dart frogs

DISCOVERIES IN SCIENCE

Evolution and Life on Earth

1753

Carolus Linnaeus publishes the first of two volumes containing the classification of all known species. In doing so, Linnaeus establishes a consistent system for naming and classifying species. The system is widely used thereafter.

1859

Charles Darwin suggests that natural selection is the mechanism of evolution. Within months, public debates regarding the truth and significance of his theory ensue.

Galápagos tortoises

1907

In his book, *Plant Breeding,* Hugo de Vries, Dutch botanist, joins Mendel's laws of heredity with the newer theory of mutation. De Vries asserts that inheritable mutations are the mechanism by which species change and new species form.

1960

Mary and Jonathan Leakey discover fossil bones of a human ancestor, *Homo habilis,* in Olduvai Gorge, Tanzania.

Mary Leakey, paleoanthropologist

1974

Donald Johansen discovers a fossilized skeleton of one of the first hominids, *Australopithecus afarensis*. This specimen was nicknamed "Lucy."

Skull of *A. afarensis*

1980

Walter and Luis Alvarez, Frank Asaro, and Helen Michel publish a paper providing evidence that 65 million years ago, an asteroid collided with Earth and caused severe environmental changes. The changes may have led to the extinction of the majority of species that lived during that time.

1994

Reinhardt Kristensen and Peter Funch discover a tiny animal living on the lips of lobsters. They name the new species *Symbion pandora*. This species is so different from other animals that scientists classify it within a new phylum, Cycliophora, within kingdom Animalia.

2006

A team of biologists announces a study of Camiguin Island, the smallest island of the Philippines. They find 54 species of birds and 24 of species of mammals.

As-yet-unnamed parrot species

Beetles—one of the most diverse groups of animals on Earth

BIOLOGY CAREER

Museum Curator

Rob DeSalle

Rob DeSalle is a curator in the Division of Invertebrate Zoology at the American Museum of Natural History in New York City. He is an adjunct professor at Columbia University and City University of New York and is a Distinguished Research Professor at New York University. His current research focuses on molecular evolution in various organisms, including pathogenic bacteria and insects.

DeSalle enjoys being a scientist because he can investigate the diversity of life every day. He also enjoys the opportunity to serve as a mentor to students. Most of all, he enjoys the thrill of discovering something that no one else on the planet has found.

He considers his most significant accomplishment in science to be his work communicating scientific ideas through his writing and museum exhibitions.

Besides his work, DeSalle loves baseball and is a passionate fan of the Chicago Cubs.

Fossil and eggs of dinosaur called *oviraptor*

Chapter Planner 17

Population Genetics and Speciation

	Standards	Teach Key Ideas
CHAPTER OPENER, pp. 396–397 (15 min.)	*National Science Education Standards*	
SECTION 1 Genetic Variation, pp. 399–403 (45 min.) › Population Genetics › Phenotypic Variation › Measuring Variation and Change › Sources of Genetic Variation	LSGene 1, LSGene 3, LSEvol 1, UCP3, SI2	**Bellringer Transparency** **Visual Concepts** Population • Population and Gene Movement • Comparing Single Allele, Multiple Allele, and Polygenic Traits • Mutation
SECTION 2 Genetic Change, pp. 404–410 (90 min.) › Equilibrium and Change › Sexual Reproduction and Evolution › Population Size and Evolution › Natural Selection and Evolution › Patterns of Natural Selection	LSGene 2, LSEvol 1, LSEvol 4, LSInter 4, LSBeh 3, UCP3, UCP4, HNS2	**Bellringer Transparency** **Transparencies** D20 Two Kinds of Selection **Visual Concepts** Hardy-Weinberg Genetic Equilibrium Example • Comparing the Effects of Random and Nonrandom Mating • Genetic Drift • Natural Selection • Directional Selection • Stabilizing Selection
SECTION 3 Speciation, pp. 411–414 (45 min.) › Defining Species › Forming New Species › Extinction: The End of Species	LSEvol 1, LSEvol 2, LSEvol 4, LSEvol 5, LSInter 3, LSBeh 2, LSBeh 3, UCP1, UCP4	**Bellringer Transparency** **Visual Concepts** Reproductive Isolation • Geographic Isolation

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 416
- SE Chapter Review, p. 417
- SE Standardized Test Prep, p. 419
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER Fast Track *Thorough instruction will require the times shown. Topics in this Chapter support math-related curriculum objectives.*

Basic Learners

- TE Normal Distribution, p. 401
- TE Genetic Mutations, p. 408
- TE Reproductive Isolation, p. 413
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Species Divergence, p. 412
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key
SE Student Edition
TE Teacher's Edition
Chapter Resource File
Workbook
Transparency
CD or CD-ROM
* Datasheet or blackline master available
■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Normal Variation, p. 397*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 396 SE **Reading Toolbox,** p. 398	
TE **Blood Types,** p. 402	SE **Quick Lab** Alleles: The Next Generation, p. 403*■ **Quick Lab** Using Random Sampling*	TE **Reading Toolbox** Visual Literacy, p. 400 SE **Reading Toolbox** Everyday Words in Science, p. 401 TE **Reading Toolbox** Everyday Words in Science, p. 401 TE **Math Skills** Mean, Median, and Mode, p. 401 TE **Reading Toolbox** Visual Literacy, p. 402	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Genetic Bottleneck,** p. 406 SE **Wild Laboratories,** p. 410	SE **Quick Lab** Genetic Risk Assessment, p. 407*■ SE **Inquiry Lab** Genetic Drift, p. 415*■ **Skills Practice Lab** Determining Growth Rate*	SE **Reading Toolbox** Visual Literacy, p. 400 TE **Reading Toolbox** General Statements, p. 408 TE **Reading Toolbox** Visual Literacy, p. 410	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Demonstration** Recognizing Subtle Differences, p. 411 TE **Demonstration** Forming a New Species, p. 412		TE **Reading Toolbox** Using Words, p. 412 SE **Science Skills** Mating Activity of Frogs, p. 413 SE **Reading Toolbox** Outlining, p. 413 TE **Reading Toolbox** Outlining, p. 413	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners
- TE Prefixes Micro- and Macro, p. 399
- TE Normal Distribution, p. 401
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Multilingual Glossary

Struggling Readers
- TE Paired Reading, p. 404
- TE Reproductive Isolation, p. 413
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Special Education Students
- TE Allele Frequency Model, p. 404
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide*■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Alternative Assessment
- TE Identifying Genotypes and Phenotypes, p. 400
- TE How Populations Evolve, p. 405
- Science Skills Worksheets*
- Section Quizzes*■
- Chapter Tests A, B, and C*■

Chapter 17

Overview

The purpose of this chapter is to explain genetic variation and change in greater detail. Scientists study polygenic phenotypes by measuring each individual in the population and then analyzing the distribution of the measurements. Students will learn that populations are subject to many forces and undergo constant genetic change, and that species that exist at any time are the net result of both speciation and extinction.

READING TOOLBOX

Assessing Prior Knowledge The students should understand the following concepts:

- populations and communities
- genotype and phenotype
- natural selection
- evolution

Visual Literacy Ask students to list some physical shell variations that might affect the survival and reproduction of the species. (examples: color of stripes, brightness of stripes, hardness of shell, size of shell, shape of shell, ability to blend in with the environment)

Chapter 17

Population Genetics and Speciation

Preview

Why It Matters

The fields of ecology, genetics, and evolutionary theory are brought together to understand how genetic changes in populations result in changes to species over time.

Every population, such as this group of banded wood snails, contains variation. Some of this variation can be seen, but much is hidden in DNA.

Chapter Correlations *National Science Education Standards*

LSGene 1 In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA.

LSGene 2 Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition there is a pair of chromosomes that determine sex.

LSGene 3 Changes in DNA (mutations) occur spontaneously at low rates.

LSEvol 1 Species evolve over time.

LSEvol 2 The great diversity of organisms is the result of more than 3.5 billion years of evolution.

LSEvol 4 The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

LSEvol 5 Biological classifications are based on how organisms are related.

LSInter 3 Organisms both cooperate and compete in ecosystems.

LSInter 4 Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite.

LSBeh 2 Organisms have behavioral responses to internal changes and to external stimuli.

LSBeh 3 Like other aspects of an organism's biology, behaviors have evolved through natural selection.

UCP1 Systems, order, and organization

UCP3 Change, constancy, and measurement

UCP4 Evolution and equilibrium

SI2 Understandings about scientific inquiry

HNS2 Nature of scientific knowledge

InquiryLab

Normal Variation

15 min

Variation is normal and is evident in all populations. Just look down.

Procedure

1. Read step 2, and prepare a table for the class data.
2. Use a **ruler or tape-measure** to measure the length of one of **your shoes** to the nearest centimeter. Record this number, as well as your shoe size and gender. Share these data with the class.
3. Make a table of the shoe lengths of everyone in your class. In the first column, record the name of each student. In the second column, record each shoe length.
4. Make a tally of the numbers of each shoe size in your class.

Analysis

1. **Compare** the table that you made in step 3 to the tally that you made in step 4.
2. **Describe** how the table you made in step 3 could be converted into a tally like that of step 4.
3. **Propose** additional methods by which these kinds of data could be collected and analyzed.
4. **Predict** how the tally that you made in step 4 would change if the data for males were deleted.

Banded wood snails (also called *grovesnails*) eat plant parts and are very common in gardens and moist habitats.

InquiryLab

Teacher's Notes Tell students to measure the bottom of their shoes from tip to heel.

Materials

- ruler or tape measure

Answers to Analysis

1. Students should note that both methods represent the same data, but the tally represents data shown in a simpler manner (shows sizes instead of lengths), shows data clusters, and makes the patterns in the data more obvious at a glance.
2. Each shoe size could be correlated to a range of shoe lengths (in cm), and then each shoe length would be converted to shoe size and tallied.
3. Students may suggest other ways to survey shoe sizes or to graph the data; some students may suggest making a histogram (a special type of bar graph, used later in this chapter).
4. The average would probably move toward smaller shoe sizes.

Key Resources

Interactive Tutor

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Everyday Words in Science Many words that we use every day have special meanings in science. For example, *matter* in everyday use is a topic, issue, or problem. In science, *matter* is the substance of which all things are made.

Your Turn Make a table like the one shown here.

1. Before you read, write in your own words the everyday meaning of the terms in the table.
2. As you read, fill in the scientific meaning for the terms in the table.

Everyday Words in Science

Word	Everyday Meaning	Science Meaning
normal		
distribution		
drift		
fitness		

Using Language

General Statements A general statement often summarizes the features of a group or describes an average or typical feature of members of the group. But if many features are summarized, some individuals in the group probably do not share all of those features. And if an average feature is described, some members of the group will not match the average. So, general statements may be true most of the time, but not always.

Your Turn Use what you know about general statements to complete the following tasks.

1. Write a general statement about apples, bananas, tomatoes, and peanuts.
2. List exceptions to the statement "Humans are bigger than monkeys."

Taking Notes

Outlining Outlining is a note-taking skill that helps you organize information. An outline can give you an overview of the topics in a chapter and help you understand how the topics are related.

Your Turn Create outlines for each section of this chapter. Start with the example shown here.

1. Copy all of the headings for a section, in order, on a piece of paper.
2. Leave plenty of space between each heading.
3. As you read the material under each heading of a section, write the important facts under that heading on your outline.

Population Genetics and Speciation
- *Genetic Variation*
  - *Population Genetics*
  - *Phenotypic Variation*
  - *Measuring Variation and Change*
    - *Studying Alleles*
    - *Allele Frequencies*
  - *Sources of Genetic Variation*
- *Genetic Change*
  - *Equilibrium and Change*

READING TOOLBOX

Using Words

1. Sample answers: *normal:* "regular" or "not strange"; *distribution:* "the way something is spread out"; *drift:* "wander"; *fitness:* "good health"
2. Check that students have prepared their table as shown in the example and that they complete their table by the end of the chapter.

Using Language

1. Sample answer: Apples, bananas, tomatoes, and peanuts are fruits.
2. Sample answers: Some baby humans are shorter than some adult monkeys. Most monkey arms are proportionally longer than human arms.

Taking Notes

Check that students have prepared their outline as shown in the example and that they complete their outline by the end of the chapter.

Section 1

Genetic Variation

Key Ideas	Key Terms	Why It Matters
How is microevolution studied? How is phenotypic variation measured? How are genetic variation and change measured? How does genetic variation originate?	population genetics normal distribution	Without variation, evolution cannot occur.

One of Charles Darwin's contributions to biology was his careful study of variation in characteristics, such as the many flower colors shown in **Figure 1.** As you have learned, Darwin knew that heredity influences characteristics, but he did not know about genes. We now know a great deal about genes. We are able to study and predict the relationships between genotypes and phenotypes. We can also study the genetic variation and change that underlie evolution.

Population Genetics

Recall that evolution can be studied at different scales, from that of microevolution to macroevolution. And recall that *microevolution* is evolution at the level of genetic change in populations. **Microevolution can be studied by observing changes in the numbers and types of alleles in populations.** The study of microevolution in this sense is **population genetics.** Thus, the studies of genetics and evolution are advancing together. Furthermore, the link from micro-evolution to macroevolution—*speciation*—can be studied in detail.

Reading Check ***What do we now know about heredity that Darwin did not know? (See the Appendix for answers to Reading Checks.)***

population genetics the study of the frequency and interaction of alleles and genes in populations

Figure 1 Genetic variation is found in all living things and forms the basis on which evolution acts. **What kinds of variation can be seen in this photograph?**

Section 1

Focus

This section explains how evolutionary changes in populations are studied and estimated, how populations evolve, and the forces that affect allele frequencies in populations.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Oberserving Variation Bring in pictures of different plants and animals, and ask students if they think genetic variation exists within these examples. (Sample answer: Yes, there are many observable differences in each individual.) Ask students to make a list of the variations they see. (Answers should include factors such as hair color, weight, height, size, flower shape, flower color, and leaf shape.) Ask students if they think these observable traits can change and, if so, what might cause the change. (Answers will vary.) LS **Visual**

Answers to Caption Questions

Figure 1: variation in flower color and plant height

Differentiated Instruction

English Learners

Prefixes Micro- and Macro- Write the words *microevolution* and *macroevolution* on the board, and underline the prefixes *micro-* and *macro-*. Tell students that *micro-* means "small" and that *macro-* means "large." Ask students how these meanings might relate to evolution. (Microevolution refers to evolution on a smaller scale than macroevolution. For example, macroevolution would deal with the evolution of entire groups of organisms, such as flowering plants or mammals, whereas microevolution deals with genetic changes within species.) LS **Verbal**

Key Resources

Visual Concepts
Population
Population and Gene Movement
Comparing Single Allele, Multiple Allele, and Polygenic Traits
Mutation

Teach, *continued*

Teaching Key Ideas

Human Heredity Most students transfer what they learn about Mendelian genetics to the inheritance pattern for all traits, including those in humans. Stress that in humans, very few traits involve only one gene with two alleles. In fact, most human traits are the result of polygenic inheritance. In addition to height, polygenic traits include weight, skin color, and metabolic rate. Explain that the way most genes interact in polygenic traits is not well understood.

READING TOOLBOX

Visual Literacy Have students look at **Figure 3,** and ask them why a normal distribution is often called a "bell-shaped curve." Ask them what grade (in a traditional A–F grading system) most students would get if a teacher grades "on a curve." (C grade) How would the number of A grades compare to the number of F grades? (very similar) **LS Visual**

Answers to Caption Questions

Figure 3: The more genes that affect a character, the more variations there can be.

Figure 2 Eye color is a polygenic character. Different genes control different pigments, which combine to produce various shades of blue, green, or brown.

Phenotypic Variation

Before anyone understood genetics, the only kind of variation that could be observed and measured was phenotypic variation. Gregor Mendel was the first to suspect that some kind of inherited units determined the various phenotypes that he observed. (In Mendel's day, the term *phenotype* was not used.) We now know that the inherited units are alleles. Mendel used his data on phenotypes to mathematically deduce the ratio of alleles in each individual. Today, we call these ratios *genotypes*.

Mendel's work was made simple by the fact that he studied pea plants with only two phenotypes for each character. As you have learned, genetics is rarely so simple. For example, listing every possible phenotype for height in humans would be difficult. If you compare many humans, you find a range of possible heights, with many slight variations.

The variety of phenotypes that exist for a given character depends on how many genes affect that character. Recall that a character that is influenced by several genes is a *polygenic* character. Human height and human eye color, for example, are polygenic. Polygenic characters may exist as a variety of traits, as shown in **Figure 2,** or a range of trait values, as shown in **Figure 3.**

❯ Biologists study polygenic phenotypes by measuring each individual in the population and then analyzing the distribution of the measurements. A *distribution* is an overview of the relative frequency and range of a set of values. Mathematically, a distribution is a tally or a histogram with a smooth line to show the overall pattern of the values.

Often, some values in a range are more common than others. For example, suppose that you were to collect one shoe from each student in your class. If you ordered and grouped the shoes by size, you would probably form a hill-shaped curve such as the one shown in **Figure 3.** This pattern of distribution is called a **normal distribution** or a *bell curve*. "Normal" in this case simply means a tendency to cluster around an average value (mean, median, or mode).

❯ Reading Check ***Why do polygenic characters vary so much?***

Figure 3 Measurements of characters that have a wide range of variation, such as shoe size, can be arranged into a histogram and are likely to form a bell curve. **❯ How do the number of genes for a character relate to its variation?**

Differentiated Instruction

Alternative Assessment

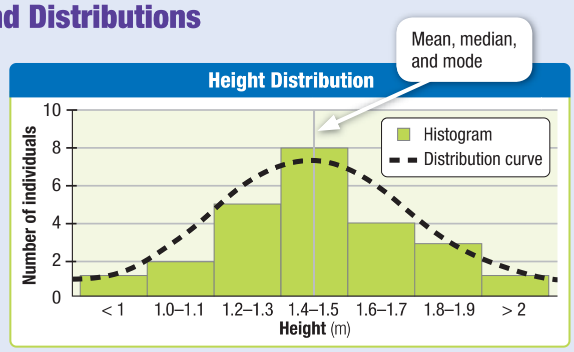
Identifying Genotypes and Phenotypes Have students identify all the possible genotypes for a hypothetical character controlled by two genes. Each gene has two alleles: *X* and *x* represent the alleles for one gene, and *Y* and *y* represent the alleles for a second gene. (*XXYY, XXYy, XXyy, XxYY, XxYy, Xxyy, xxYY, xxYy, xxyy*) Ask how the variety of this character would compare to the variety of a character that is determined by three genes. (The character determined by three genes would have greater variety.) **LS Logical**

Math Skills — Histograms and Distributions

Suppose that you were to measure the height of every student in your school. You would probably gather a wide range of data. The best way to graph this data would be to use a histogram. A *histogram* is a special kind of bar graph for displaying a range of values. The histogram clearly shows the range of values as well as the values that are most common.

To make a histogram, list the values in order from smallest to largest. Then, determine the *range* from the smallest value to the largest. Draw the *x*-axis of the histogram to cover this range. Then, group the values into convenient intervals. For example, values for height in meters could be grouped into intervals of 0.2 m each, as shown here.

Next, count the number of values that fall within each interval. (Hint: Making a tally of the counts is helpful.) Draw the *y*-axis of the histogram to allow for the highest count in any one interval. Finally, draw bars to show the count for each interval. The bars should touch each other because the graph is showing a continuous range of data.



You can use math software to make a histogram and further analyze these kinds of data. For example, you can "fit a curve" to the data, adding a line through the bars to show the general shape, or *distribution*, of the data. You can group the data into smaller or larger intervals, or add or subtract values, and then see changes in the shape of the curve. Finally, you can find the mean, median, and mode(s) of the data. A *normal distribution* will have similar values for the mean, median, and mode.

Measuring Variation and Change

To study population genetics, we need to study how genes in populations change over time. To measure these changes, we must look at how alleles are passed on from generation to generation as organisms mate and produce offspring. The particular combination of alleles in a population at any one point in time makes up a *gene pool*.

Studying Alleles To study genetic variation, we need to estimate the number of alleles in a population. For characters with simple Mendelian inheritance, we can estimate by using simple math combined with our knowledge of genetics. For example, we may start by counting the number of individuals in the population and recording the phenotype of each. Then, we can deduce each genotype.

As you have learned, to keep track of alleles, we can represent alleles with letters. For example, a particular gene may have two alleles, *R* and *r*. In addition, we represent genotypes as combinations of alleles. So, if two alleles exist for a particular gene, then there are three genotypes: *RR*, *Rr*, and *rr*. To compare the numbers of alleles or genotypes, we measure or calculate the frequency of each. ❯ **Genetic variation and change are measured in terms of the frequency of alleles in the gene pool of a population.** A *frequency* is the proportion or ratio of a group that is of one type.

❯ **Reading Check** *What is the main measure of genetic variation?*

normal distribution a line graph showing the general trends in a set of data of which most values are near the mean

READING TOOLBOX

Everyday Words in Science The word *normal* in science and math is often used to describe measurements that fit within a normal distribution. What does a doctor mean when talking about "normal height" for a person of your age?

Math Skills

Mean, Median, Mode Have students identify the mean, median, and mode for the data in the histogram at the top of the page. (In this case, all three values are represented by the line in the center of the graph.) LS Logical

Teaching Key Ideas

Gene Pool Review the meaning of *gene pool*. Point out that if a particular gene has two alleles, *R* and *r*, then the gene pool contains these two alleles. Explain that an actual gene pool will have more than two alleles because an organism has genes for more than one character. Emphasize that many characters are polygenic, so most individuals will have a variety of traits. Ask what the range distribution for a polygenic trait would look like if the values were plotted on a graph. (a bell curve) LS Verbal

READING TOOLBOX

Everyday Words in Science *Normal height* refers to a range of heights that fall in the center of a histogram of heights for a person of that age. LS Verbal

Differentiated Instruction

Basic Learners/English Learners

Normal Distribution Have students work in groups. Give each group 50 peanuts (in the shell) or a similar item. Have them measure the peanuts in millimeters and graph their results with a tally or histogram. *Caution:* If using peanuts, be sure no students are allergic to them. An alternative for peanuts would be to use some fresh green beans or small carrots in a bag from the produce department of your grocery. Have each group share their graphs with the class. LS Kinesthetic

Teach, *continued*

Answers to Caption Questions

Figure 4: No. Even if an allele is dominant, it may not be the most frequent allele in a population.

READING TOOLBOX

Visual Literacy Help students relate **Figure 4** to the genotype-frequency equations. Have them locate the attached earlobe on the circle graph and note the percent of genotype frequencies represented by this part of the whole. (32%) Ask how the genotype for this trait is represented. (by *ee*) Next, have students look at the first equation and find "*frequency of ee*". Point out that in the equation "*frequency of ee*" has been replaced with the value 0.32, representing 32%. Note that the other values have been derived in a similar manner. Then, ask students to relate the 1 in the equation to the graph. (It represents 100% of genotype frequencies). LS **Visual**

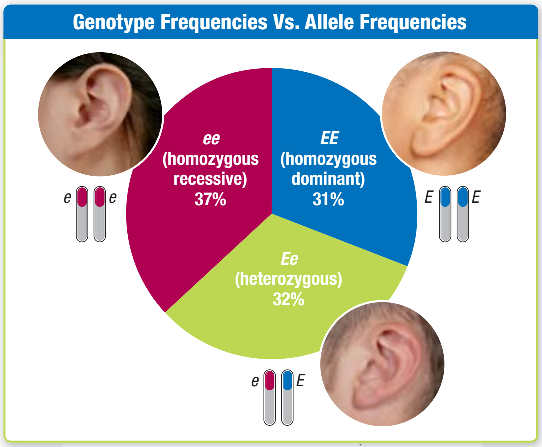


Figure 4 You cannot see alleles, and you cannot always tell genotype based on phenotype. You have to use math and know dominance patterns to calculate allele frequencies. › **Is the dominant allele always the most frequent?**

SCILINKS.
www.scilinks.org
Topic: Genotype/Phenotype
Code: HX80662

Tracking Frequencies To study genetic change, biologists want to keep track of the frequency of each allele in a population over time. They can keep track in several ways. A direct way would be to detect and count every allele in every individual, which is rarely practical. An indirect way is to use mathematics along with a knowledge of how alleles combine. Recall that alleles combine to form genotypes that, in turn, produce recognizable phenotypes.

To understand the basic mathematics of allele frequencies, consider the simple example shown in **Figure 4.** Human ear lobes have two phenotypes: unattached (free hanging) or attached at the base. The ear lobe character is thought to be controlled by a single gene, and the unattached trait is thought to be dominant. So, the unattached allele is represented as *E*, and the attached allele is represented as *e*. People with attached ear lobes are homozygous recessive, or genotype *ee*. People with unattached ear lobes are either homozygous dominant (*EE*) or heterozygous (*Ee*).

Genotype Frequencies Notice how genotype frequencies differ from allele frequencies. Suppose that the population in **Figure 4** consists of 100 people. In this case, 37% of the population, or 37 people, are genotype *ee*; 32 are *Ee*; and 31 are *EE*. Keep in mind that in ratios and percentages, all of the parts add up to one whole, or 100%. So, the sum of genotype frequencies in a population should always be equal to 1 (or 100%). This fact leads to the following equation:

$$(\text{frequency of } EE) + (\text{frequency of } Ee) + (\text{frequency of } ee) = 1$$

Using the numbers in our example, the equation proceeds as follows:

$$0.31 + 0.32 + 0.37 = 1$$

Allele Frequencies Similarly, the sum of allele frequencies for any gene must equal 1, as in the following equation:

$$(\text{frequency of } E) + (\text{frequency of } e) = 1$$

or

$$\frac{(\text{count of } E)}{(\text{total})} + \frac{(\text{count of } e)}{(\text{total})} = 1$$

In our example population, there are 94 *E* alleles and 106 *e* alleles, and the total is 200 alleles. The equation proceeds as follows:

$$\frac{94}{200} + \frac{106}{200} = 0.47 + 0.53 = 1$$

As you can see, the frequency of the *E* allele is 0.47, and the frequency of the *e* allele is 0.53. Notice that the dominant allele is not necessarily the most frequent! Also keep in mind that you often cannot tell genotypes by looking at phenotypes. However, you will soon learn how these equations can be used to track changes in populations.

› **Reading Check** ***What is the sum of all allele frequencies for any one gene?***

Why It Matters

Blood Types Tell students that allele frequencies in humans often differ among populations. The alleles for the ABO blood groups are an example. The chart shows genotype frequencies for several populations. LS **Visual**

Blood Types in Populations Within the United States

Blood Types (genotypes)	Caucasians	African Americans	Alaskan Eskimos	Navajo
O (*ii*)	45%	49%	38%	73%
A (I^Ai)	40%	27%	44%	27%
B (I^Bi)	11%	20%	13%	0%
AB (I^AI^B)	4%	4%	5%	0%

Hands-On

QuickLab

15 min

Alleles: The Next Generation

Model the allele frequencies in a population over time.

Procedure

1. Work in a group, which will represent a population. Obtain **two colors of marbles (one pair) for each member in the group.** Each color will represent a unique allele. Choose one color to be "dominant."
2. Mix the marbles. Each member of the "population" should randomly take two "alleles." Record the resulting genotype and phenotype of each member.
3. Each member should hide one marble in each hand and then randomly exchange one of these "alleles" with another member. Record the resulting genotypes and phenotypes of each member.
4. Repeat the steps to model four more "generations."

Analysis

1. **Determine** the genotype and phenotype ratios for each "generation." Do the ratios change over time?
2. **Propose** a way to change the ratios in your population from one generation to the next. Propose a way that this change could happen in a real population.

Sources of Genetic Variation

Evolution cannot proceed if there is no variation. As you have learned, this variation must originate as new alleles. **The major source of new alleles in natural populations is mutation in germ cells.**

Mutation is important, but it generates new alleles at a slow rate. New alleles first arise in populations as changes to DNA in the sperm and ova (called *germ* cells) of individuals. If a germ cell with a mutation goes on to form offspring, then a new allele is added to the gene pool. Mutations can also occur in nongerm cells (called *somatic* cells), but these mutations are not passed on to offspring.

Academic Vocabulary

generate produce; bring into being; cause to be

Reading Check *Why is mutation so important?*

Section 1 Review

KEY IDEAS

1. **Describe** the scope of population genetics.
2. **Explain** how polygenic phenotypes are studied.
3. **Describe** how genetic variation and change can be measured.
4. **Identify** the major source of genetic variation in a population.

CRITICAL THINKING

5. **Analyzing Concepts** Even in cases of simple Mendelian inheritance within a population, the ratio of phenotypes of a specific character is rarely the same as the ratio of alleles for that character. Explain why these ratios differ.
6. **Applying Logic** Can an individual organism evolve in the Darwinian sense? Explain your answer in terms of genetic variation within populations.

MATH SKILLS

7. **Distribution Curves** Suppose that **Figure 3** represents the distribution of shoe sizes in a class of twelfth graders. How might the distribution change if the shoes of a class of first graders were added to those of the twelfth graders? Explain your answer.

Answers to Section Review

1. Population genetics is the study of microevolution by observing changes in the numbers and types of alleles in populations.
2. Polygenic phenotypes are studied by measuring many individuals in a population and then analyzing the patterns in the data.
3. Genetic variation and change are measured in terms of the frequency of alleles in the gene pool of a population.
4. mutation
5. Ratios differ because of dominance. Phenotypes that are homozygous dominant and heterozygous for a characteristic will appear identical. Only individuals that are homozygous recessive for that characteristic will have a different phenotype.
6. Individual organisms cannot evolve. With more individuals and genetic variation in a population, more opportunities exist for members of that population to survive and reproduce. Evolution of populations is dependent on genetic variation of alleles combined with differences in survival among individuals.
7. The normal distribution would have two "hills"; that is, the shoe sizes would have two different average values (modes): the average height of the younger students on the left side of the graph, and the average values of the older students on the right side of the graph. The mean would lie in between these hills, but few values would fall there.

QuickLab

Teacher's Notes If groups have less than five people, students should exchange alleles with the same person more than once.

Materials

- marbles, two different colors

Answers to Analysis

1. The ratios should remain about the same for all generations.
2. Marbles could be added or subtracted; alleles could be added or subtracted.

Close

Formative Assessment

The sum of all allele frequencies in a population at any time is called ______.

A. polygenic (Incorrect. This refers to a character influenced by several genes.)
B. genotype frequency (Incorrect. This refers to the frequency of genotypes in a population at a given time.)
C. a phenotypic variation (Incorrect. This refers to the variations of observable traits among individuals.)
D. a gene pool (Correct! The gene pool consists of all possible alleles present in a population at a given time.)

Section 2

Section 2 Genetic Change

Key Ideas	Key Terms	Why It Matters
❯ What does the Hardy-Weinberg principle predict? ❯ How does sexual reproduction influence evolution? ❯ Why does population size matter? ❯ What are the limits of the force of natural selection? ❯ What patterns can result from natural selection?	genetic equilibrium	The mathematics of genetics can be used to make predictions about future generations.

❯ Focus

The purpose of this section is to explain the Hardy-Weinberg principle, the forces that can change allele frequencies how each force can affect populations, and how natural selection can change the distribution of traits in populations.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Teaching Key Ideas

Allele Frequencies Tell students that polydactyly (extra fingers) in humans is caused by a dominant allele. Ask students if therefore, they think the frequency of polydactyly should be increasing, decreasing, or staying the same. (Some students may think that it must be increasing since dominant alleles "overpower" recessive alleles.) Explain that the Hardy-Weinberg equation shows that allele frequency will remain the same if no evolutionary forces are acting.

You might think that a dominant trait would always be the most common trait in a population. When biologists began to study population genetics, they found that this was not always true.

Equilibrium and Change

In 1908, the English mathematician G. H. Hardy and the German physician Wilhelm Weinberg began to model population genetics by using algebra and probabilities. They showed that in theory, the frequency of alleles in a population should not change from one generation to the next. Moreover, the ratio of heterozygous individuals to homozygous individuals (the genotype frequencies) should not change. Such a population, in which no genetic change occurred, would be in a state of **genetic equilibrium.**

Measuring Change Genetic change in a population can be measured as a change in genotype frequency or allele frequency. A change in one does not necessarily mean a change in the other. For example, as shown in **Figure 5,** the genotype frequencies changed between generations, but the allele frequencies did not.

Figure 5 Allele frequencies can remain stable while genotype frequencies change.

Allele Frequencies in Two Generations

Genotype frequency	Allele frequency	Generation
RR (red) = 0.5 *Rr* (pink) = 0.5 *rr* (white)= 0	*R* = 0.75 *r* = 0.25	1 
RR (red) = 0.625 *Rr* (pink) = 0.25 *rr* (white)= 0.125	*R* = 0.75 *r* = 0.25	2 

Key Resources

Transparencies
D20 Two Kinds of Selection

Visual Concepts
Hardy-Weinberg Genetic Equilibrium Example
Comparing the Effects of Random and Nonrandom Mating
Genetic Drift
Natural Selection
Directional Selection
Stabilizing Selection

Differentiated Instruction

Struggling Readers

Paired Reading Assign students to cooperative pairs. Have each student copy the blue and red headings of section onto a piece of paper. Then, have them read each passage silently. As they read, have them indicate parts they understand with a check mark and parts they do not understand with a question mark. After reading each passage, have the partners discuss what they did or did not understand. **LS Verbal**

Math Skills Hardy-Weinberg Equation

The Hardy-Weinberg principle can be expressed as an equation that can be used to predict stable genotype frequencies in a population.

The equation is usually written as follows:

p^2	+	$2pq$	+	q^2	=	1
(frequency of *RR* individuals)		(frequency of *Rr* individuals)		(frequency of *rr* individuals)		(sum of all frequencies)

Recall that the sum of the genotype frequencies in a population must always equal 1.

By convention, the frequency of the more common of the two alleles is referred to as p, and the frequency of the rarer allele is referred to as q.

Individuals that are homozygous for allele *R* occur at a frequency of p times p, or p^2. Individuals that are homozygous for allele *r* occur at the frequency of q times q, or q^2.

Heterozygotes have one copy of *R* and one copy of *r*, but heterozygotes can occur in two ways—*R* from the father and *r* from the mother, or *r* from the father and *R* from the mother. Therefore, the frequency of heterozygotes is $2pq$.

Hardy-Weinberg Principle Hardy and Weinberg made a mathematical model of genetic equilibrium. This model is the basis of the *Hardy-Weinberg principle.* **The Hardy-Weinberg principle predicts that the frequencies of alleles and genotypes in a population will not change unless at least one of five forces acts upon the population.**

genetic equilibrium a state in which the allele frequencies of a population remain in the same ratios from one generation to the next

Forces of Genetic Change In reality, populations are subject to many forces and undergo genetic change constantly. **The forces that can act against genetic equilibrium are gene flow, nonrandom mating, genetic drift, mutation, and natural selection.**

Gene Flow *Gene flow* occurs when genes are added to or removed from a population. Gene flow can be caused by *migration,* the movement of individuals from one population to another, as shown in **Figure 6.** Each individual carries genes into or out of the population, so genetic frequencies may change as a result.

Nonrandom Mating In sexually reproducing populations, any limits or preferences of mate choice will cause nonrandom mating. If a limited set of genotypes mates to produce offspring, the genotype frequencies of the population may change.

Genetic Drift Chance events can cause rare alleles to be lost from one generation to the next, especially when populations are small. Such random effects on allele frequencies are called *genetic drift*. The allele frequencies are changed directly and genotype frequencies change as a result.

Mutation A mutation can add a new allele to a population. Allele frequencies are changed directly, if only slightly.

Natural Selection Natural selection acts to eliminate individuals with certain traits from a population. As individuals are eliminated, the alleles for those traits may become less frequent in the population. Thus, both allele and genotype frequencies may change.

Reading Check *What can cause gene flow?*

Figure 6 These caribou are migrating from one place to another. If they meet other groups of caribou and interbreed, gene flow may occur.

Teaching Key Ideas

$p + q = 1$ Remind students that the sum of allele frequencies for any gene must equal 1. Ask students how we know this. (We are assuming that there are only two alleles for a gene, and they are found in the frequencies of p and q. Because there are no other possibilities, the sum of the two frequencies must be 1, or 100 percent of the possible alleles.) If both sides of the equation $p + q = 1$ are squared, the equation still holds true, because we treat both sides of the equation in the same manner. The result is $p^2 + 2pq + q^2 = 1$.) Tell students that the Hardy-Weinberg equation applies to any trait, no matter how many alleles are involved. For example, blood type is controlled by three alleles (A, B, and O). In this case, $p + q + r = 1$, where p, q, and r represent the frequencies of the three alleles. LS Logical

Differentiated Instruction

Special Education Students

Allele Frequencies Model Help visually impaired students understand the information in **Figure 5** by providing a kinesthetic model. Cover wooden alphabet blocks to mask the markings on the wood. Label each block with raised lettering, or Braille, for the genotypes in generations 1 and 2 of **Figure 5.** Allow students to feel each group of blocks that represents generations 1 and 2. Have them determine the genotype and allele frequencies for each generation. Use these materials to represent other crosses and generations. LS Kinesthetic

Alternative Assessment

How Populations Evolve Have students use cause-and-effect graphic organizers to show the five forces that cause populations to evolve: mutation, gene flow, nonrandom mating, genetic drift, and natural selection. LS Visual

Teach, *continued*

Teaching Key Ideas

The Founder Effect Ask students to imagine a population of 100 birds inhabiting a coastal area. Two alleles, *W* and *w*, affect wing color. *W* is the dominant allele that produces red wings; *w* is the recessive allele that produces white wings. In this population, 96 out of 100 birds have red wings (64 *WW* and 32 *Ww*); only 4 have white wings (*ww*). A hurricane blows 10 birds 500 miles out to sea, where they land on a small island. Two of the birds have white wings (*ww*); 8 have red wings (4 *WW*, 4 *Ww*). Have students determine the frequency of the *w* allele in the new population. (Total alleles = 20; *W* = 12/20, or 60%; *w* = 8/20, or 40%.) Point out that the frequency of allele *w* has jumped from 20% to 40%! Tell students that this form of genetic drift is called the "founder effect" and is similar to the effect of inbreeding or population size reduction. **LS Logical**

go.hrw.com
interact online

Students can interact with populations by going to go.hrw.com and typing in the keyword HX8POPF8.

Figure 7 Sexual selection favors the development of extreme phenotypic traits in some species. The vibrant red stripe on the blue muzzle of this male mandrill baboon does not appear in females.

Sexual Reproduction and Evolution

Recall that sexual reproduction creates chances to recombine alleles and thus increase variation in a population. So, sexual reproduction has an important role in evolution. **Sexual reproduction creates the possibility that mating patterns or behaviors can influence the gene pool of a population.** For example, in animals, females sometimes select mates based on the male's size, color, ability to gather food, or other characteristics, as shown in **Figure 7.** This kind of behavior is called *sexual selection* and is an example of nonrandom mating.

Another example of nonrandom mating is *inbreeding*, in which individuals either self-fertilize or mate with others like themselves. Inbreeding tends to increase the frequency of homozygotes, because a smaller pool of alleles is recombined. For example, populations of self-fertilizing plants consist mostly of homozygotes. However, inbreeding does not change the overall frequency of alleles. Inbreeding is more likely to occur if a population is small.

Population Size and Evolution

Population size strongly affects the probability of genetic change in a population. **Allele frequencies are more likely to remain stable in large populations than in small populations.** In a small population, the frequency of an allele can be quickly reduced by a chance event. For example, a fire or drought can reduce a large population to a few survivors. At that point, each allele is carried in a few individuals. The loss of even one individual from the population can severely reduce an allele's frequency. So, a particular allele may disappear in a few generations, as shown in **Figure 8.** This kind of change is called *genetic drift* because allele frequencies drift around randomly. The force of genetic drift is strongest in small populations. In a larger population, alleles may increase or decrease in frequency, but the alleles are not likely to disappear.

Reading Check *What is the genetic effect of inbreeding?*

Figure 8 Alleles are more likely to be lost from smaller populations. So, variation tends to decrease over time in smaller populations but not in larger populations.

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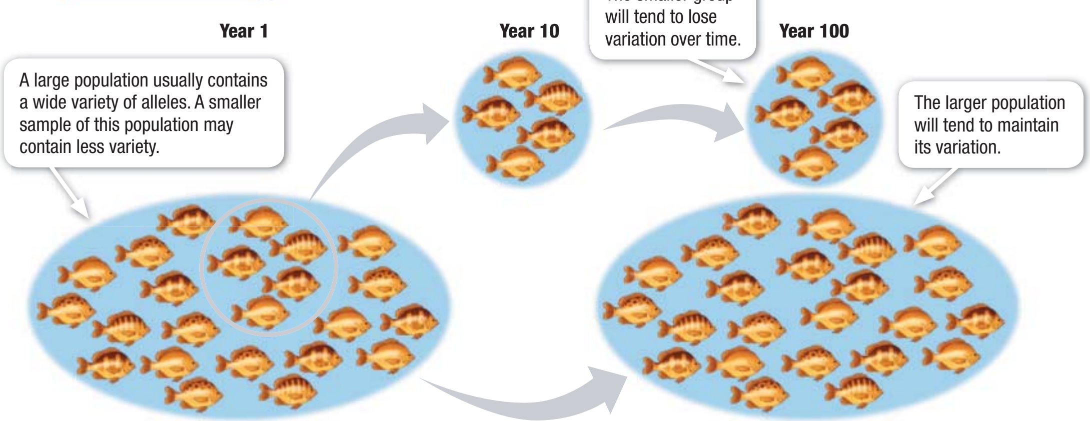

Why It Matters

Genetic Bottleneck The cheetah is a species whose evolution has been seriously affected by genetic drift. Cheetahs have undergone drastic population declines within the last 5,000 years. As a result, the cheetahs alive today are descendants of only a few individuals, and each cheetah is genetically similar to other cheetahs. This kind of drastic reduction in the variation of a gene pool is called a *genetic bottleneck*. One consequence of the cheetahs' current genetic uniformity is a reduced ability to survive diseases. This lack of genetic diversity makes cheetahs more vulnerable to extinction than the other large cats, perhaps even more than some cats that have smaller populations.

Data

QuickLab

⏱ 15 min

Genetic Risk Assessment

How can the Hardy-Weinberg equation be used? It can be used to predict the risk of genetic disorders in a population. For example, medical professionals may know how many people have been diagnosed with a genetic disorder. From this information, they can predict how many people are at risk of passing on the disorder.

Procedure

1. Consider these facts: Cystic fibrosis (CF) is a disorder that occurs in 1 out of every 2,500 Caucasians in North America. CF is caused by a recessive allele.
2. Use the Hardy-Weinberg equation to predict the percentage of carriers of the allele that causes CF.

Lungs of a person with cystic fibrosis

Analysis

1. **Calculate** the frequency of the recessive allele.
2. **Calculate** the frequency of the dominant allele.
3. **Calculate** the frequency of carriers (heterozygotes).
4. **Determine** how many of every 1,000 Caucasian North Americans are likely to carry the cystic fibrosis allele.

Natural Selection and Evolution

Recall that Charles Darwin proposed natural selection as a mechanism that could drive evolution. Scientists have studied many examples of natural selection in action.

How Selection Acts Keep in mind that the process of natural selection is a result of the following facts.

- **All populations have genetic variation.** Any population has an array of individuals that differ slightly from one another in genetic makeup. Although this variation may be obvious in humans, variation also exists in species whose members may appear identical, such as a species of bacteria.
- **Individuals tend to produce more offspring than the environment can support.** Individuals of a population often struggle to survive, whether competing with one another or not.
- **All populations depend upon the reproduction of individuals.** Some biologists have noted that "evolutionary fitness is measured in grandchildren." The statement means that an individual must survive to reproduce, and also produce offspring that can reproduce, to pass its genes on to future generations.

Genetic Results of Selection The result of natural selection is that the frequency of an allele may increase or decrease depending on the allele's effects on survival and reproduction. Natural selection causes deviations from genetic equilibrium by directly changing the frequencies of alleles. Although natural selection is not the only force of evolution, it is a powerful force.

› Reading Check *How is "fitness" measured in evolutionary terms?*

SCILINKS.
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Topic: Natural Selection
Code: HX81016

ACADEMIC VOCABULARY

deviate to turn aside; to diverge or differ

QuickLab

Teacher's Notes Hardy-Weinberg proportions seldom, if ever, occur in nature because at least one of the five forces of evolution is always affecting populations.

Answers to Analysis

1. If q^2, the frequency of recessive homozygotes, is 0.0004, then q is the square root of 0.0004, or 0.02.
2. $p + q = 1$, $p = 1 - q$. So, $p = 1 - 0.02$, or 0.98.
3. $2pq = 2 \times 0.98 \times 0.02 = 0.0392$
4. 39 of every 1,000 Caucasian North Americans would be predicted to carry the cystic fibrosis allele unexpressed (without disease).

Teaching Key Ideas

Changing Allele Frequency Have groups of students come up with scenarios that result in a change in the frequency of a particular allele. Have groups answer the following questions about their scenarios: What change occurred? What genetic variations existed in individuals before and after the change? What characteristics of the new environment contributed to changing the frequency of alleles? **LS Logical**

MISCONCEPTION ALERT

Individuals Do Not Evolve A common misconception is that *individuals* evolve, changing to match changes in the environment. Explain that natural selection acts on a *population*, where less fit individuals are less likely to pass on their genes. This causes a shift in the genetic makeup of the population as a whole. The genetic makeup of individual organisms in the population does not change within those individuals' lifetimes.

Teach, *continued*

Answers to Caption Questions

Figure 9: A colorless crayfish that was previously adapted for a dark environment might be found by predators more easily when placed in a well-lit environment.

Teaching Key Ideas

Natural Selection and Phenotypes Reinforce the concept that natural selection operates on phenotypes and not genotypes. Show students two photographs, one of a canine population in which differences among phenotypes are obvious and one of another species in which phenotypic differences are not very apparent. The latter could be one of penguins, which, also, form large populations of sexually reproducing individuals. Point out that no two penguins are exactly alike and that every penguin is able to recognize its mate, offspring, and nesting-ground neighbors. Ask students what type of variations in the phenotypes might be favored by natural selection. (Answers will vary.) **LS Visual**

READING TOOLBOX

General Statements Sample answer: some phenotypes may be barely successful yet not be removed; some combinations of phenotypes may succeed better than others. **LS Logical**

Figure 9 Crayfish species exist in a variety of colorations. In many cases, the coloration helps the crayfish hide from predators or attract mates. But for crayfish species that live in lightless caves, having color gives no fitness advantage. **What might happen to a colorless crayfish placed in a well-lit pond?**

READING TOOLBOX

General Statements List possible exceptions to the statement "Natural selection removes unsuccessful phenotypes from a population."

Why Selection Is Limited The key lesson that scientists have learned about evolution by natural selection is that the environment does the selecting. If the environment changes in the future, the set of characteristics that are most adaptive may change. For example, each of the animals shown in **Figure 9** is adapted to a specific environment and may not be able to survive if placed in another environment.

Natural selection is limited by nature. **Natural selection acts only to change the relative frequency of alleles that exist in a population.** Natural selection cannot direct the creation of new alleles, nor will it necessarily delete every allele that is not adaptive. So, natural selection does not create perfectly adapted organisms.

Indirect Force Natural selection does not act directly on genes. It merely allows individuals who express favorable traits to reproduce and pass those traits on to their offspring. Darwin's idea of natural selection, stated in modern terms, is that **natural selection acts on genotypes by removing unsuccessful phentoypes from a population.** Biologists say that certain phenotypes are "selected against" and that certain genotypes are thus "favored."

Role of Mutation Think carefully about how natural selection might operate on a new allele that has arisen by mutation. At first, the mutation may make no difference. Even if the mutation results in a nonfunctional protein, the cell may have a functional copy of the original gene as its second allele. However, the new, nonfunctioning version could be passed on as a recessive allele. This kind of mutation is the probable origin of many recessive genetic disorders.

Only characteristics that are expressed can be targets of natural selection. Therefore, selection cannot operate against rare recessive alleles, even if they are unfavorable. A recessive allele must become common before two heterozygous individuals (carriers) are likely to mate and produce homozygous offspring. Only then does natural selection have an opportunity to act. And even then, selection will act only against homozygotes. For this reason, genetic disorders can persist in populations.

Reading Check *How can unfavorable alleles persist?*

Differentiated Instruction

Basic Learners

Genetic Mutations Have students research different genetic mutations found in nature and explain how the phenotype is either favorable or unfavorable in a given environment for the individual. Have them predict the outcome for the individual with the genetic mutation. Students should share their results with the class. **LS Verbal**

Patterns of Natural Selection

Recall that many traits, such as human height, have a bell-curve distribution in natural populations. When natural selection acts on polygenic traits, it essentially acts to eliminate some part of the bell curve.

❯ **Three major patterns are possible in the way that natural selection affects the distribution of polygenic characters over time. These patterns are directional selection, stabilizing selection, and disruptive selection,** as **Figure 10** illustrates.

Directional Selection In *directional selection,* the "peak" of a normal distribution moves in one direction along its range. In this case, selection acts to eliminate one extreme from a range of phenotypes. Thus, the alleles for the extreme phenotype become less common in the population. This pattern of selection is often seen in the evolution of single-gene traits, such as pesticide resistance in insects.

Stabilizing Selection In *stabilizing selection,* the bell-curve shape becomes narrower. In this case, selection eliminates individuals that have alleles for any extreme type. So, the ratio of intermediate phenotypes increases. In other words, this pattern of selection tends to "stabilize" the average by favoring a narrow range of phenotypes. Stabilizing selection is very common in nature.

Disruptive Selection In *disruptive selection,* the bell curve is "disrupted" and pushed apart into two peaks. In this case, selection acts to eliminate individuals with average phenotype values. Each peak is pushed in an opposite direction, away from the average. The result is increasingly distinct or variable phenotypes in the population. Mathematically, the new distribution is said to have two mode values, each of which differs from the mean value.

❯ **Reading Check** ***Which form of selection increases the range of variation in a distribution?***

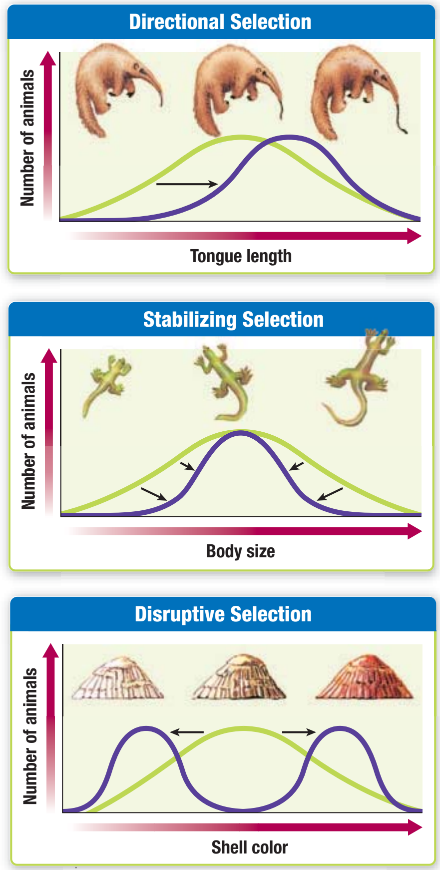


Figure 10 Selection can shift a distribution from an original bell curve (green) toward a new shape (purple).

Section 2 Review

❯ KEY IDEAS

1. **Restate** the Hardy-Weinberg principle in your own terms.
2. **Relate** sexual reproduction to evolutionary forces.
3. **Explain** why a small population is subject to genetic drift.
4. **Describe** the limits of the force of natural selection.
5. **List** the patterns that can result from natural selection acting on polygenic traits.

CRITICAL THINKING

6. **Comparing Concepts** In what way is the genetic effect of nonrandom mating similar to the genetic effect of gene flow?
7. **Reasoning Opinions** Are all organisms perfectly adapted for their habitat? Explain.

USING SCIENCE GRAPHICS

8. **Prediction** Redraw each of the graphs in **Figure 10.** Use as examples birds with a range of beak sizes. Describe possible situations that would cause each pattern of selection.

Teaching Key Ideas

Visual Literacy Test students' understanding of **Figure 10.** Ask: How might a shorter tongue affect the anteater's survival? (A shorter tongue reaches a shorter distance, so fewer ants are reached.) Why might a mid-size salamander have an advantage over larger or smaller ones? (A smaller one might be caught easily while a larger one might have difficulty finding enough food.) How can either of two shell colors be advantageous to barnacles? (The environment might contain different colored surfaces.) **LS Logical**

❯ Close

Formative Assessment

Natural selection indirectly affects ______ by removing unsuccessful ______ from a population.

A. phenotypes, genotypes (Incorrect. Natural selection does not act directly on genes.)
B. populations, genotypes (Incorrect. Natural selection acts upon genotypes in a population by removing phenotypes.)
C. genotypes, phenotypes (Correct. The gene pool is indirectly changed by removing individuals with specific phenotypic traits from the population.)
D. individuals, genotypes (Incorrect. Natural selection acts upon genotypes by removing individuals with specific phenotypes.)

Answers to Section Review

1. Neither allele nor genotype frequencies should change unless a force, such as natural selection or genetic drift, acts on a population.
2. Sexual reproduction creates the possibility that mating patterns or behaviors can cause genetic change and thus act as a force of evolution.
3. Allele frequencies are more likely to become unstable in small populations.
4. Natural selection is limited by nature; it can only act to change the relative frequency of commonly expressed alleles that exist in a population.
5. directional selection, stabilizing selection, and disruptive selection
6. Both change genotype frequencies with addition or removal of individuals from the gene pool.
7. No, natural selection cannot direct the creation of new alleles, and it will not necessarily delete every allele that is not adaptive.
8. Student graphs should show all three patterns of selection using a scale of beak sizes from small to large. Situations should include changes that would affect the fitness value of certain sizes of beak. For example, availability of two very different seed types might cause disruptive selection on bill sizes.

Why It Matters

Teacher's Notes For each type of "specialist" shown here, called an "ecomorph" by biologists, there are at least four different Caribbean anole species that have that same kind of specialization. A *radiation* is a pattern of divergence from a few ancestors into many new species within an area and period. The anoles (genus *Anolis*) of the Caribbean Islands seem to have evolved in this pattern, as did the Galápagos finches that were first observed by Charles Darwin.

READING TOOLBOX

Visual Literacy Have students look closely at each specialist and point out the differences that might help each to survive in its environment. LS Visual

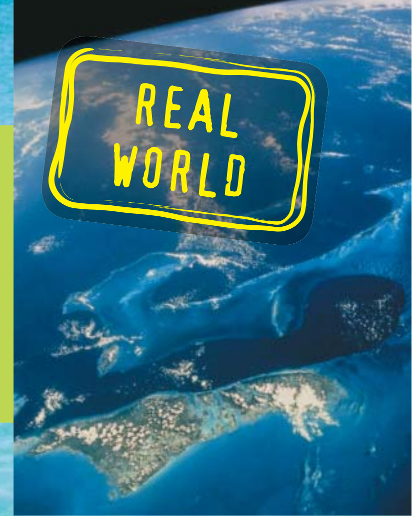
Answer to Quick Project

There are 138 species in the Caribbean and about 340 species of anoles overall. There are probably over 500 Hawaiian species of *Drosophila*; about 380 species have been described.

Why It Matters

Wild Laboratories

REAL WORLD



What do the finches of the Galápagos Islands, the anole lizards of the Caribbean Islands, and the *Drosophila* flies of the Hawaiian Islands have in common? Each of these groups of related species has been extensively studied by evolutionary biologists. And each group has undergone a similar pattern of evolution on each group of islands.

Roles in the Landscape

Darwin found that each Galápagos finch species ate certain types of food and had a beak that was adapted for that food. Similarly, biologists have found that each Caribbean anole species tends to live in a certain part of the landscape and has body parts adapted for running, climbing, or hiding in that area. On each Caribbean island, a unique set of species fulfills each "specialist" role.

Trunk-Crown Specialist *Anolis allisoni* specializes in crawling along the tops and trunks of tropical plants.

Trunk-Ground Specialist *Anolis lineatopus* specializes in running along tree trunks and the ground.

Twig Specialist *Anolis angusticeps* specializes in clinging to twigs.

Grass-Bush Specialist *Anolis bahorucoensis* specializes in clinging to grass and stems.

Quick Project Find out how many species of anoles have been identified in the Carribbean islands as compared with the total number of anole species worldwide. Likewise, find out the number of Hawaiian species of flies in the family Drosophilidae.

Section 3

Speciation

Key Ideas	Key Terms	Why It Matters
❯ How can species be defined? ❯ How do we know when new species have been formed? ❯ Why is studying extinction important to understanding evolution?	reproductive isolation subspecies	How we define species relates to how we study evolution and ecology.

All of the beetles in **Figure 11** belong to the same species, but each looks different. Identifying species or telling species apart is often difficult. Part of the difficulty lies in the very definition of *species*.

Defining Species

Since the days of Darwin, scientists have understood that species are not permanent, stable things. And thanks to Mendel, scientists have learned that genetics underlie the variation and change in species. With this knowledge, they have reconsidered the very definition of *species*. ❯ **Today, scientists may use more than one definition for *species*. The definition used depends on the organisms and field of science being studied.** Increasingly, scientists want to do more than name and describe things—they want to know how things are related.

As you have learned, a *species* is generally defined as a group of natural populations that can interbreed. This definition is based on the *biological species concept*, which adds the requirement that the interbreeding produce healthy, fertile offspring. Applying this concept, any populations that do not share future offspring could be considered separate species.

However, the biological species concept cannot be applied to all organisms. It does not apply to those that reproduce asexually or that are known only from fossils. And any form of reproduction may be difficult to confirm. So, species may instead be defined based on their physical features, their ecological roles, and their genetic relatedness.

❯ **Reading Check** *Why is a species hard to define?*

Figure 11 How many species of beetles are in this photo? Just one! ❯ What problems arise when defining species based on appearances?

Section 3

❯ Focus

This section explains how scientists define a species and how they know when a new species is formed. It also discusses extinction and how it relates to evolution and speciation.

Bellringer

Use the Bellringer transparency to prepare students for this section.

❯ Teach

Demonstration

Recognizing Subtle Differences Use a bird field-guide and show pictures of nearly identical birds within a family, such as wrens, warblers, and sparrows. Ask students how these similar-looking species were identified. (by their physical features and their ecological roles) What problems might exist in using this method of identifying the birds? (Sample answer: Birds of the same species might have differences in plumage color between sexes and among different ages.) How else might the birds be classified? (Accept all reasonable answers.) **LS Logical**

Answers to Caption Questions

Figure 11: Species that look alike may be different; species that look diferent may be the same.

Key Resources

Visual Concepts
Reproductive Isolation
Geographic Isolation

Teach, *continued*

Answers to Caption Questions

Figure 12: ecological niche, mating behavior, polyploidy, and hybridization

Demonstration

Forming a New Species Organize students into small groups. Have each group brainstorm and select an existing species and create a fictitious set of circumstances that would create divergence within the population, resulting in speciation. Each group should draw both the existing species and new species and explain how natural selection acted upon the populations. Post the drawings on the bulletin board and have each group discuss their predictions. **LS Verbal**

READING TOOLBOX

Using Words Ask students what the word *net* means in everyday usage. (Sample answer: "open-meshed material commonly used to catch something") Point out *net* in the boldfaced sentence in the second paragraph. Ask what *net* means in the sentence. (Sample answer: "overall" or "total") **LS Verbal**

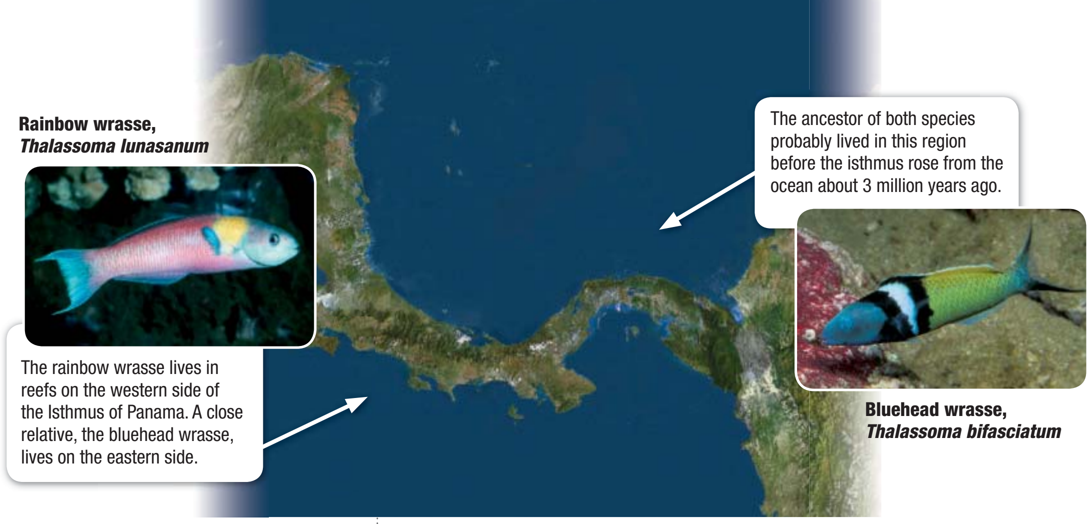


Figure 12 These two species probably evolved from a single species that was separated into two groups by geographic change. **› What other mechanisms can isolate species?**

reproductive isolation a state in which a population can no longer interbreed with other populations to produce future generations

subspecies a taxonomic classification below the level of species; refers to populations that differ from, but can interbreed with, other populations of the same species

Forming New Species

Each population of a single species lives in a different place. In each place, natural selection acts on the population and tends to result in offspring that are better adapted to the environment. If the environments differ, the adaptations may differ. The accumulation of differences between populations is called *divergence* and can lead to the formation of new species.

Recall that *speciation* is the process of forming new species by evolution from preexisting species. Speciation rarely occurs overnight; it usually occurs in stages over generations. **› Speciation has occurred when the net effects of evolutionary forces result in a population that has unique features and is reproductively isolated.**

Reproductive Isolation Recall that the biological species concept defines species as interbreeding groups. Thus, if two groups stop interbreeding, they take a step toward speciation. **Reproductive isolation** is a state in which two populations can no longer interbreed to produce future offspring. From this point on, the groups may be subject to different forces, so they will tend to diverge over time.

Through divergence over time, populations of the same species may differ enough to be considered subspecies. **Subspecies** are simply populations that have taken a step toward speciation by diverging in some detectable way. This definition is imprecise because reproductive isolation is only apparent after the passage of time.

Mechanisms of Isolation Divergence and speciation can happen in many ways. Any of the following mechanisms may contribute to the reproductive isolation of populations.

- **Geography** A physical barrier, such as the one shown in **Figure 12**, may arise between populations. Such a barrier could prevent interbreeding. Over time, if the populations diverge enough, they will probably not interbreed even if the barrier is removed.

Differentiated Instruction

Advanced Learners/GATE

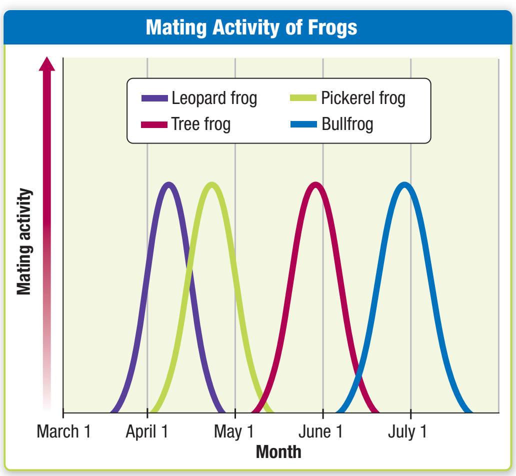
Species Divergence Ask students to research an animal species, such as the black bear, and how a subspecies, such as the Florida black bear, may have diverged. Have them share the results of their research with the class. **LS Verbal**

- **Ecological Niche** Recall that the *niche* of a species is the role that the species has in its environment, including all of its interactions with other species. Divergence can occur when populations use different niches. The divergence of multiple lineages into many new species in a specific area and time is called *adaptive radiation.*
- **Mating Behavior and Timing** Many species that sexually reproduce have specific behaviors for attracting mates, such as a pattern of sounds or actions. Some undergo mating at specific times or in response to environmental events. If two populations develop differences in these behaviors, they may no longer attract each other for mating. This mechanism seems to be responsible for the species divergence shown in **Figure 13.**
- **Polyploidy** Recall that a *polyploid* organism has received a duplicate set of chromosomes by accident. A polyploid individual may be reproductively isolated because it cannot pair gametes with others from the original population. However, it may reproduce by vegetative growth, self-fertilize, or find a polyploid mate. In these cases, a new species can arise rapidly. Polyploidy has been observed in many plant species.
- **Hybridization** In some cases, two closely related species may come back into contact with each other and attempt to mate. The offspring of such a mating are called *hybrids.* In cases in which the two parent species are sufficiently diverged from each other, their offspring may be sterile. For example, a mule is a sterile hybrid of a horse and a donkey. Another possibility is that hybrid offspring may not be well adapted to the environment of either parent. Finally, if the parents have many genetic differences, the offspring may not develop successfully. However, there are also many cases in which hybridization leads to new and successful species.

Reading Check *Is hybridization always successful?*

READING TOOLBOX

Outlining Complete your outline for this chapter. Be sure to include each of the headings on this page, such as "Polyploidy" and "Hybridization." When you finish the chapter, review your outline and add notes to any heading whose meaning is unclear to you.



Pickerel frog, *Rana palustris*

Leopard frog, *Rana pipiens*

Figure 13 The pickerel frog and the leopard frog are closely related species. Differences in mating times may have caused their reproductive isolation. **What other aspects of mating can push populations to diverge?**

Science Skills

Mating Activity of Frogs Have students refer to **Figure 13.** Ask students to predict how reproductive isolation might result in different mating times of the original species. (The original population may have become geographically isolated, resulting in different mating times due to differences in the microclimate.) **LS Logical**

READING TOOLBOX

Outlining Remind students that an outline should summarize information and not repeat it verbatim. **LS Verbal**

Answers to Caption Questions

Figure 13: other aspects of behavior, or genetics of sexual reproduction (such as chromosome number)

Differentiated Instruction

Basic Learners/Struggling Readers

Reproductive Isolation Have students create a chart listing the five mechanisms that may contribute to the reproductive isolation of a population. Ask them to research and list an animal or plant that has or could become an example of speciation as a result of each mechanism. (*Geography:* Kaibab and Aberts squirrels becoming separated by the Grand Canyon; *Ecological Niche:* some green anoles now occupying different niches because of competition with brown anoles; *Mating Behavior and Timing:* pickerel and leopard frogs have separate mating times; *Polyploidy:* bananas are triploid crops; *Hybridization:* wolves and dogs produce fertile offspring) **LS Verbal**

Teach, continued

Answer to Caption Question

Figure 14: It is the counterpart to speciation.

Teaching Key Ideas

Extinction Rate Tell students that studies of the fossil record estimate that species have disappeared on the average of one to four per year for every million species living except for five periods during the last 600 million years when the rates dramatically increased. However, scientists estimate that the rate is now 100 to 10,000 times Earth's past average.

Close

Formative Assessment

A new species forms when a population _______.

A. diverges in some way from another population (Incorrect. Populations can differ but still belong to the same species.)

B. has unique features and is reproductively isolated (Correct! These two factors together result in speciation.)

C. lives separately from another population (Incorrect. A population living separately becomes a new species only if it develops unique features and is reproductively isolated.)

D. produces no offspring (Incorrect. With no offspring, the population will become extinct.)

Figure 14 The Tasmanian wolf was driven to extinction by ranchers and dogs in Australia in the early 1900s. **What is the role of extinction in evolution?**

SCILINKS.
www.scilinks.org
Topic: Extinction
Code: HX80558

Extinction: The End of Species

Extinction occurs when a species fails to produce any more descendants. The animal in **Figure 14** is extinct. Extinction, like speciation, can be detected only after it is complete. And extinction is as much a part of evolution as speciation is. Scientists estimate that more than 99% of all of the species that have ever lived on Earth have become extinct. **The species that exist at any time are the net result of both speciation and extinction.** If you think of speciation as a branching of a "family tree," then extinction is like the loss of one of the branches.

As you will learn, many cases of extinction are the result of environmental change. Almost all of the dinosaurs died off because of some combination of meteorite impacts, volcanism, and climate change on Earth millions of years ago. Anytime that an environment changes, species that were once well adapted may become poorly adapted. If the environment changes more rapidly than new adaptations arise within a species, the species may be driven to extinction.

Reading Check *When do we know that extinction has happened?*

Section 3 Review

KEY IDEAS

1. **Identify** two definitions of *species* used in evolutionary biology.
2. **Summarize** a general process by which one species can evolve into two species.
3. **Relate** extinction to changes that occur in the numbers and types of species over time.

CRITICAL THINKING

4. **Making Inferences** Would the biological species concept be useful for classifying bacterial species? Explain your answer.
5. **Relating Concepts** Relate the idea of reproductive isolation to the biological species concept.
6. **Describing Relationships** Describe the relationship between speciation and extinction in terms of a "family tree" of descent.

ALTERNATIVE ASSESSMENT

7. **Speciation-in-Action Poster** Sometimes, the easiest way to explain a concept is to illustrate real-world examples of the concept. Create a poster that illustrates examples of reproductive barriers between species. Show how these barriers relate to the biological species concept. Present your poster to the class.

Answers to Section Review

1. A species can be defined as a group of natural populations that can interbreed and produce fertile offspring or as a group of organisms with specific physical features, ecological roles, and genetic relatedness.
2. Two populations of the same species can become reproductively isolated. From this point on, the groups may be subject to different forces, so they will tend to diverge over time. Eventually, the populations may become different species that can no longer interbreed.
3. Extinction reduces the number of species and changes the competition for resources.
4. Sample answer: Not always, because many bacteria reproduce asexually.
5. Reproductive isolation occurs when a population is unable to produce fertile offspring with other populations. The biological species concept defines a species as a group of natural populations that can interbreed.
6. Speciation is the beginning of a lineage of a species; extinction is the end of a lineage of a species.
7. Posters should illustrate reproductive barriers such as two species living in different habitats, differing coloration of males of two species, differing chromosomal numbers that would lead to non-viable zygotes, or size differences between members of different species.

Inquiry

Chapter 17 Lab

45 min

Objectives

- Investigate the effect of population size on genetic drift.
- Analyze the mathematics of the Hardy-Weinberg principle.

Materials

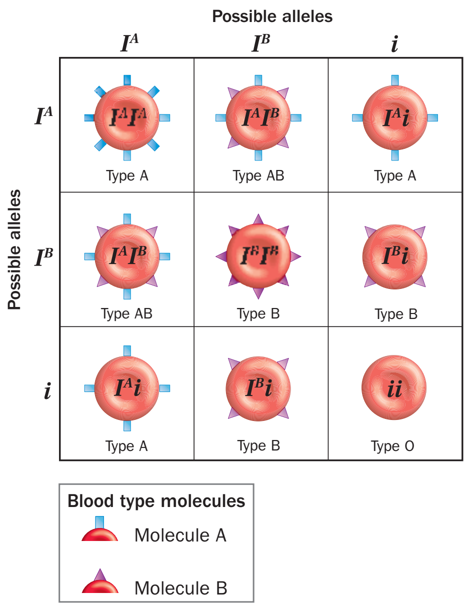
- buttons, blue (10 to 100)
- buttons, red (10 to 100)
- buttons, white (10 to 100)
- jar or beaker, large, plastic

Genetic Drift

Random chance affects the frequencies of alleles in a population over time. This effect, called *genetic drift,* also depends on population size.

Preparation

1. SCIENTIFIC METHODS **State the Problem** How does population size affect allele frequencies? Read the procedure to see how you will test this.
2. SCIENTIFIC METHODS **Form a Hypothesis** Form a hypothesis that predicts the results of this procedure for three different population sizes.



Procedure

1. Prepare to model the populations. First, assign each color button to one of the alleles (I^A, I^B, or i) of the ABO blood types. Notice how each possible pairing of alleles matches one of the four types (A, B, AB, or O). Then, choose three different population sizes. Also choose one ratio of alleles at which to start all three populations (for example, I^A:I^B:i = 2:2:1). Create tables for your data.
2. Represent the first population's alleles by placing the appropriate number of blue, red, and white buttons in a jar.
3. Randomly select two buttons from the jar to represent one person. Record this person's genotype and phenotype. Place the buttons back into the jar.
4. Repeat step 3 until you have modeled the appropriate number of people in the population. Tally the total number of each allele within this generation.
5. Empty the jar. Refill it with the number and color of buttons that matches the tallies recorded in step 4.
6. Repeat steps 3 through 5 until you have modeled four generations.
7. Repeat steps 2 through 6 to model two more populations.

Analyze and Conclude

1. **Analyzing Data** Describe any changes in genotype and phenotype ratios within each population over time.
2. **Explaining Results** Did any population maintain genetic equilibrium? Explain how you can tell.
3. SCIENTIFIC METHODS **Analyzing Results** Which popultion showed the greatest amount of genetic drift? Explain.

Lab

Time Required

25 minutes

Ratings

EASY → HARD

- **Teacher Prep** 1
- **Student Setup** 1
- **Concept Level** 2
- **Cleanup** 1

Tips and Tricks

Stop students periodically during this activity, and ask them to predict what will happen next. Because the process is random, predictions are not likely to hold. However, students may begin to see the risk that certain alleles (button colors) will disappear from the population. When students repeat this activity with a different population size, they should begin to see that the effect of drift, loss of alleles, is stronger in smaller populations.

Answers to Analyze and Conclude

1. Answers will vary. Most populations should undergo changes in both ratios.
2. No (most likely). Genetic equilibrium would be indicated by having the same ratios in both genotype and phenotype in each successive generation.
3. The smallest population is most likely to show the greatest amount of drift. (This may not hold true if differences in population sizes are slight.) A single given allele makes up a greater proportion of the gene pool of a smaller population.

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 17

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the keyword **HX8POPS** to access the Super Summary for this chapter.

Reteaching Key Ideas

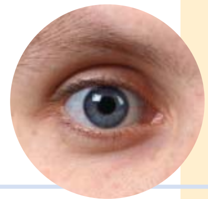
Allele Frequency Tell students that a certain population of plants contains only blue or red flowers. Blue (B) is dominant to red (b). The population has 16% red-flowered plants. Have students calculate the frequency of the red allele (0.4), of the blue allele (0.6). **LS Logical**

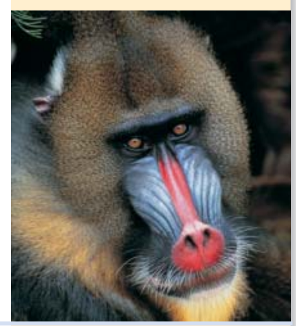
Hardy-Weinberg Principle Tell students that a fictional trait, fuzzy wings, is caused by a dominant allele and prevents birds from flying swiftly. Ask students to explain if Hardy-Weinberg genetic equilibrium is likely in the frequency of this allele. (No. A recessive, fuzzy-wing phenotype makes the bird unable to catch food or flee from predators, so natural selection is likely to act on this phenotype, and reduce the frequency of this allele.) **LS Logical**

Chapter 17 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8POPS

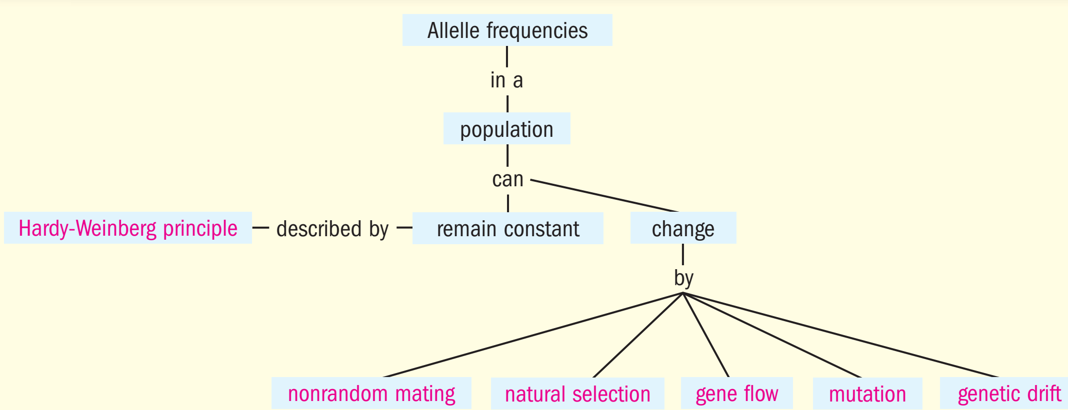
Key Ideas	Key Terms
1 Genetic Variation › Microevolution can be studied by observing changes in the numbers and types of alleles in populations. › Biologists study polygenic phenotypes by measuring each individual in the population and then analyzing the distribution of the measurements. › Genetic variation and change are measured in terms of the frequency of alleles in the gene pool of a population. › The major source of new alleles in natural populations is mutation in germ cells.	**population genetics** (399) **normal distribution** (400)
2 Genetic Change › The Hardy-Weinberg principle predicts that the frequencies of alleles and genotypes in a population will not change unless at least one of five forces acts upon the population. The forces that can act against genetic equilibrium are gene flow, nonrandom mating, genetic drift, mutation, and natural selection. › Sexual reproduction creates the possibility that mating patterns or behaviors can influence the gene pool of a population. › Allele frequencies are more likely to remain stable in large populations than in small populations. › Natural selection acts only to change the relative frequency of alleles that exist in a population. Natural selection acts on genotypes by removing unsuccessful phenotypes from a population. › Three major patterns are possible in the way that natural selection affects a distribution of polygenic characters over time. These patterns are directional selection, stabilizing selection, and disruptive selection.	**genetic equilibrium** (404)
3 Speciation › Today, scientists may use more than one definition for species. The definition used depends on the organisms and field of science being studied. › Speciation has occurred when the net effects of evolutionary forces result in a population that has unique features and is reproductively isolated. › The species that exist at any time are the net result of both speciation and extinction.	**reproductive isolation** (412) **subspecies** (412)





Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 17 Review

READING TOOLBOX

1. **Everyday Words in Science** Sometimes, words are used in science in ways that are not far from their everyday meanings, but the words need to be considered in context. For example, *drift* in the context of *genetic drift* means "to float about randomly." What does *pool* mean in the context of *gene pool*?
2. **Concept Map** Construct a concept map that describes the causes of genetic change. Try to include the following words in your map: *Hardy-Weinberg, genetic drift, nonrandom mating, natural selection, mutation,* and *gene flow*.

Using Key Terms

In your own words, write a definition for each of the following terms.

3. *normal distribution*
4. *genetic equilibrium*

Use each of the following terms in a separate sentence.

5. *gene pool*
6. *reproductive isolation*

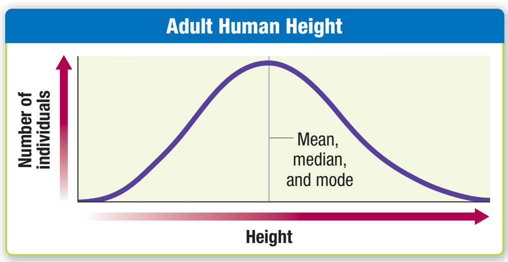
Understanding Key Ideas

7. The sum of allele frequencies in a population should be
   - **a.** equal to 1.
   - **b.** less than 100.
   - **c.** equal to the phenotype frequencies.
   - **d.** one-half of the genotype frequencies.
8. In the Hardy-Weinberg equation, $p^2 + 2pq + q^2 = 1$, what does the term $2pq$ represent?
   - **a.** frequency of heterozygous individuals
   - **b.** frequency of individuals with two alleles
   - **c.** frequency of homozygous recessive individuals
   - **d.** frequency of homozygous dominant individuals
9. Genetic drift has the greatest impact on
   - **a.** large populations.
   - **b.** small populations.
   - **c.** growing populations.
   - **d.** migrating populations.
10. Which of the following is a reason why natural selection is limited in its influence on evolution?
    - **a.** Natural selection cannot direct the creation of new alleles.
    - **b.** All populations depend on the reproduction of individuals.
    - **c.** Natural selection eliminates certain genotypes from populations.
    - **d.** Individuals tend to produce more offspring than the environment can support.
11. In evolution, *extinction* describes the end of
    - **a.** an allele.
    - **b.** a single species.
    - **c.** an individual organism.
    - **d.** a population of organisms.

Explaining Key Ideas

12. **Describe** the role of population genetics in the study of microevolution.
13. **Identify** the major source of new alleles in natural populations.
14. **Relate** natural selection to changes in allele frequencies.
15. **Describe** the effect that directional selection has on the phenotypes in a population of organisms.
16. **Describe** the difficulty with defining species.
17. **Explain** how mating behavior can contribute to reproductive isolation.

Use the diagram to answer the following question.



18. **Identify** the kind of characters in a population that will usually form a diagram like this one.

Assignment Guide

Section	Questions
1	1, 3, 5, 7, 12, 13, 18, 28, 29
2	2, 4, 8, 9, 10, 14, 15, 19, 20, 21, 22, 23
3	6, 11, 16, 17, 24, 25, 26, 27

Review

Reading Toolbox

1. a group of possibilities or options (like a pool of candidates for an election)
2. See previous page for answer to concept map.

Using Key Terms

3. a group of data where the mean, median, and mode have similar values
4. the condition in which a population does not undergo any genetic change over time
5. The human gene pool is huge because many genes are responsible for human traits.
6. The Isthmus of Panama has caused the reproductive isolation of populations that live on the two sides of the barrier.

Understanding Key Ideas

7. a 8. a 9. b 10. a
11. b

Explaining Key Ideas

12. Microevolution can be studied by analyzing changes in the numbers and types of alleles in populations. The study of microevolution in this sense is population genetics.
13. mutation in germ cells
14. Natural selection can cause the frequency of a given allele to increase or decrease depending on the allele's effects on survival and reproduction.
15. Directional selection eliminates one extreme from a range of phenotypes, so the normal distribution shifts away from this extreme.
16. Species are widely defined based on the biological species concept, but this concept is difficult to apply both in practice and to organisms that do not reproduce sexually or cannot be observed alive.
17. Some organisms undergo mating at specific times and have certain ways of attracting a mate. If two populations develop differences in these behaviors, they may no longer attract each other for mating.
18. polygenic phenotypes

Using Science Graphics

19. b

20. p^2 is the homozygous dominant genotype, $2pq$ includes the two heterozygous dominant genotypes, and q^2 is the homozygous recessive genotype. The value 1 stands for 100 percent of the genotypes in the population.

Critical Thinking

21. No, a population in genetic equilibrium does not have any genetic changes occurring. Genetic change is evolution at the smallest scale.

22. Inbreeding effectively reduces the gene pool, which increases the likelihood that two organisms will have the same alleles for a character. Therefore, the chances of the resulting offspring being homozygous for any characteristic are high. As a result, the offspring may be homozygous for many characteristics.

23. Yes, genetic drift is most significant in small populations, such as that of the cheetah. When an allele is found in only a few individuals in a population, the loss of even one individual from the population can have major effects on the allele's frequency. A result of genetic drift within a small population is genetic uniformity within the population.

24. Accept all answers that include interbreeding, physical features, genetic similarities, or other evidence of linkage by ancestry and descent.

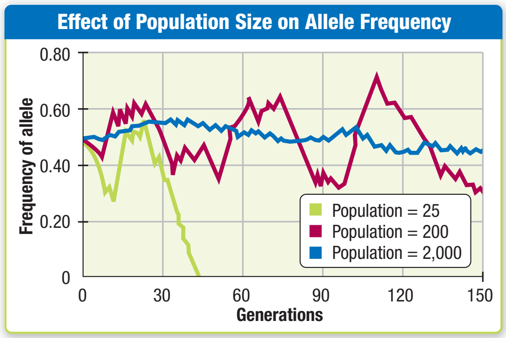
25. No, the plants are not the same species because they do not naturally interbreed in the wild. As natural populations, they are reproductively isolated.

Writing for Science

26. Students' commentaries may vary in creativity, but should show an understanding of how geographic isolation can contribute to speciation.

Using Science Graphics

Use the diagram to answer the following question.



19. This diagram represents the effect of
- **a.** gene size.
- **b.** genetic drift.
- **c.** speciation.
- **d.** population growth.

This Punnett square shows how each part of the Hardy-Weinberg equation aligns to the possible combinations of two alleles.

	R (*p*)	*r* (*q*)
R (*p*)	*RR* (p^2)	*Rr* (*pq*)
r (*q*)	*rR* (*pq*)	*rr* (q^2)

20. The Hardy-Weinberg equation states that

$$p^2 + 2pq + q^2 = 1$$

Identify from the Punnett square what each part of the equation represents.

Critical Thinking

21. Applying Logic Is a population that is in genetic equilibrium evolving? Explain your answer.

22. Explaining Processes How does inbreeding increase the frequency of homozygotes in a population?

23. Making Inferences Cheetahs have undergone drastic population declines over the last 5,000 years. As a result, the cheetahs alive today are descendants of only a few individuals, and each cheetah is almost genetically uniform with other members of the population. Do you think that genetic drift has affected the cheetah population? Explain your answer.

24. Defining Concepts Propose a definition of *species* that encompasses more than one way that species could be defined.

25. Forming Reasoned Opinions In the laboratory, a scientist studied two identical-looking daisies that belong to the genus *Aster*. The two plants produce fertile hybrids in the laboratory, but they never interbreed in nature because one plant flowers only in the spring and the other flowers only in autumn. Do the plants belong to the same species? Explain.

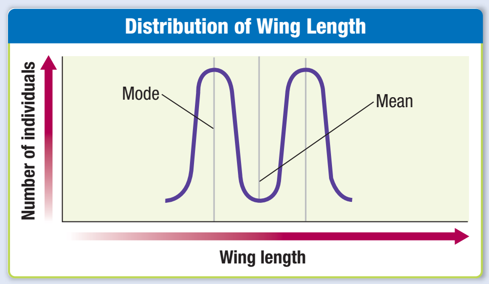
Writing for Science

26. Speciation Narration Two species of antelope squirrel live on opposite sides of the Grand Canyon. *Ammospermophilus harrisi,* or Harris's antelope squirrel, lives on the south rim, and *Ammospermophilus leucrurus,* the white-tailed antelope squirrel, lives on the north rim. Imagine that you can speed up time and witness the speciation process ocurring with these squirrels. Write a running commentary—much like that heard at a sports event—on the process of speciation that occurred after the initial population of antelope squirrels became divided on both sides of the canyon. Read or act out your commentary to the class.

Why It Matters

27. Hawaiian Speciation Conduct research to identify another Hawaiian example of adaptive radiation.

Math Skills



28. Mean, Median, and Mode Describe this distribution in terms of mean, median, and mode.

29. Math Terminology This kind of distribution is sometimes called a *bimodal* distribution. Why?

Why It Matters

27. Students should report on groups of closely related, native Hawaiian species, such as sword plants or honeycreepers.

Math Skills

28. The distribution has values that concentrate or "peak" near two different modes (most frequent values); the mean (average of all values) lies between these modes, in the center of the range of values, as does the median (center of the range).

29. There are two modes. (*Bi* means "two.")

Chapter 17 Standardized Test Prep

TEST TIP For a question about a structure or process that has a complex name, write down the name and review its meaning before answering the question.

Science Concepts

1. Population genetics is the study of
- **A** how individuals evolve.
- **B** how populations interact.
- **C** how genes determine traits.
- **D** how alleles change within populations.

2. Phenotypic variations take the form of
- **F** genetic differences between organisms.
- **G** character differences between organisms.
- **H** molecular differences between organisms.
- **J** chromosomal differences between organisms.

3. The major source of new alleles in a natural population is
- **A** mutation.
- **B** polyploidy.
- **C** genetic drift.
- **D** natural selection.

4. Which of the following is an example of non-random mating?
- **F** Genes are removed from the population when individuals migrate.
- **G** A change in a populations' allele frequency is due to chance.
- **H** An individual chooses a mate that has the brightest coloration.
- **J** An individual is eliminated from the gene pool by natural selection.

5. Random change in allele frequency due to chance alone is called
- **A** gene flow.
- **B** genetic drift.
- **C** natural selection.
- **D** sexual selection.

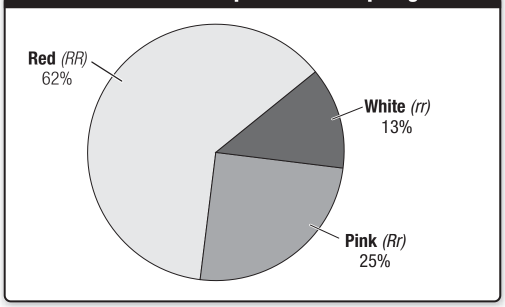
Math Skills

6. The Hardy-Weinberg equation, $p^2 + 2pq + q^2 = 1$, describes a state of equilibrium among all alleles in a population. Expressed in terms of percentages, the sum of allele frequencies in a population would be
- **F** 1%
- **G** 2%
- **H** 50%
- **J** 100%

Using Science Graphics

Use the diagram to answer the following questions.

Flower Color in a Population of Snapdragons

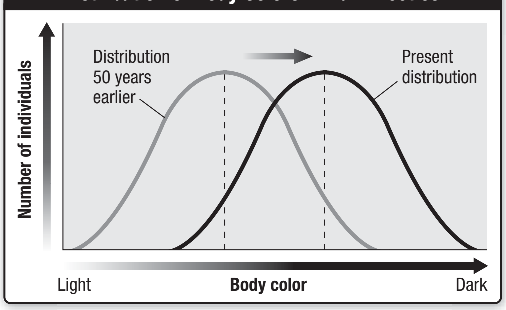


7. In this population, which genotype has the lowest frequency?
- **A** *RR*
- **B** *rr*
- **C** red
- **D** white

8. In this population, what is the frequency of heterozygotes?
- **F** 13%
- **G** 25%
- **H** 38%
- **J** 62%

Use the diagram to answer the following question.

Distribution of Body Colors in Bark Beetles



9. The diagram represents which form of selection?
- **A** sexual selection
- **B** stabilizing selection
- **C** disruptive selection
- **D** directional selection

Answers

1. D 2. G 3. A
4. H 5. B 6. J
7. B 8. G 9. D

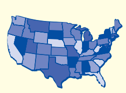
TEST DOCTOR

Question 3 **A** is correct because mutations can add new alleles to a population. **B** is incorrect. Polyploidy is when an individual receives a duplicate set of chromosomes. **C** is incorrect. Genetic drift is most evident in small populations, causing alleles to be lost. **D** is incorrect because natural selection is a force that directly changes the frequency of alleles.

Question 7 **A** is incorrect. *RR* has the highest frequency of 62%. **B** is correct. *rr* has the lowest frequency of 13%. **C** is incorrect. Red is a phenotype. **D** is incorrect. White is a phenotype.

Question 9 **A** is incorrect. Sexual selection is not one of the three main patterns in the way that natural selection affects polygenic characters over time. **B** is incorrect. Due to stabilizing selection, the bell shaped curve would become narrower. **C** is incorrect. Disruptive selection is shown by a bell curve being pushed apart into two peaks. **D** is correct. Directional selection shows the peak of a normal distribution moving in one direction along its range.

State Resources



For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

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