Learning Objectives

• 12.1 Clarify why evolution occurs only in populations, not in individuals.
• 12.2 Distinguish among directional, stabilizing, and disruptive selection.
• 12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.
• 12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.
• 12.5 Describe how DNA mutations can create new alleles at random.
• 12.6 Explain how gene flow works and how it may inhibit evolution.
• 12.7 Relate the process of genetic drift to genetic bottlenecks and the founder effect, using examples.

Next Generation Science Standard
HS-LS4.B: Natural Selection

Driving Question and Guiding Prompts

What events created new species of island-dwelling lizards and sea fan corals?
* What is the definition of a species (biological species concept)?
* Why is it necessary to have more than one definition of a species?
* How did the geography of the two islands differ for the lizards?
* How did the behavior and anatomy (internal and external) of the lizards change?
* How can speciation occur when organisms are in the same location?
* Describe the appearance of the two coral species.
* Which type of evidence is strongest when determining whether speciation has occurred?
* How can speciation occur when a population is geographically separated?
* What barriers would prevent two organisms from mating?
* What complications can arise if two different species mate and produce offspring?

Section Outline with Road Blocks and Check Your Understanding Questions

INTRODUCTION: BATTLING RESISTANCE

Key scientific topics covered:
- Mechanisms of evolution
- Penicillin, produced by mold, kills bacteria
- Natural selection results in resistance to antibiotics

Road Blocks
- Diabetes, while a very common disorder, is often not well understood by students. A quick description of the disease and why patients tend to have foot ulcers would be helpful here: diabetes can cause nerve and artery damage that can reduce blood flow and sensation, especially in the feet, which makes it easier to get ulcers and an infection.
- Most students when hearing or reading the word "ulcer" immediately think of stomach ulcers. A basic definition of an ulcer may be necessary. Merriam-Webster definition: an open sore on an external or internal surface of the body caused by a break in the skin or mucus membrane that fails to heal.

SECTION 1: BIRTH OF A SUPERBUG

Key scientific topics covered:
- MRSA (methicillin-resistant *Staphylococcus aureus*) vs. VRSA (vancomycin-resistant *Staphylococcus aureus*)
- Descent with modification
- Allele frequencies calculated as percentages in a population
- Evolutionary mechanisms

Road Blocks
- Students tend to either forget or never fully understand what an allele is. It may be useful to review this information from Chapter 7, “Patterns of Inheritance.”
- Remind students that a phenotype is the outward expression of the genotype.

Check Your Understanding Questions
1. Populations are defined as a group of individuals of the same species living and interacting in a shared environment. Why is it safe to say that only populations can evolve and not individuals?
   ANS: The change in allele frequencies within a population is how evolution is measured. Therefore, only the change in the allele frequencies of the populations shows evolution since individuals have the same genes their entire life.

2. List the four mechanisms of evolution.
   ANS: Natural selection, mutation, gene flow, and genetic drift
3. Why are bacteria ideal organisms for studying evolution?
   ANS: Bacteria evolve quickly.
   More in-depth answers may include the following: small genome, quick reproductive time, relatively inexpensive, easy to grow, and small size.

SECTION 2: RISING RESISTANCE

Key scientific topics covered:
- Natural selection as a mechanism for evolution
- Patterns of natural selection (directional, stabilizing, and disruptive)
- Convergent evolution

Road Blocks
- Students learned about homologous traits in Chapter 11. Use this information to differentiate between homologous and analogous traits. For example, show how a butterfly and a bird both have wings but are obviously not related. They simply have the same environmental selection pressures.

Check Your Understanding Questions
1. How does natural selection lead to evolution?
   ANS: Natural selection is the natural process of one or more alleles that enable organisms to better survive, thus allowing longer survival, more opportunities for reproduction, and more beneficial genes into the next generation.

2. What is the risk of exposing bacteria to vancomycin?
   ANS: Those bacteria with alleles resistant to vancomycin will, by natural selection, live longer and reproduce more, thus creating a new generation of vancomycin-resistant bacteria.

3. List and describe the three common patterns of natural selection and sketch a graph of each.
   a. Disruptive selection
      ANS: The population that exhibits either extreme of an inherited trait has an advantage over individuals with an intermediate phenotype.
b. Stabilizing selection
ANS: Individuals with intermediate values of an inherited phenotypic trait have an advantage over other individuals in the population.

![Stabilizing Selection Diagram]

Before

After

c. Directional selection
ANS: (Most common form) Individuals at one of the extremes of an inherited phenotypic trait have an advantage over other individuals in the population.

![Directional Selection Diagram]

Before

After

4. What does convergent evolution cause?
ANS: Convergent evolution causes distantly related organisms to evolve similar structures based on similar environmental pressures.
A more in-depth answer may be the following: organisms appear very much alike regardless of different genetics.

SECTION 3: ENTER ENTEROCOCCUS
Key scientific topics covered:
• Mutation as a mechanism for evolution
• Gene flow
• Horizontal gene transfer
• Migrants move alleles from one population to another
Road Blocks
• Students may not recall the difference between mitosis and meiosis, which can hinder their understanding of how mutations can be passed from one generation to the next. A quick image review of the two processes and purpose of each process will be helpful here.
• In sexually reproducing organisms, mitosis occurs in body cells and is used for growth, repair, and development.
• Meiosis is the process of producing sex cells for reproduction that results in genetic variation.

Check Your Understanding Questions
1. How are new alleles generated?
   ANS: New alleles are generated through mutations.
   A more in-depth answer may be the following: a mutation is the change in the sequence of any DNA segment.

2. If a mutation occurs and a new allele is produced, but that mutation does not get passed to offspring, what will happen to that mutation?
   ANS: The mutation will not contribute to evolution.

3. In a human, mutations are passed to offspring only if in the germ line cells; how are mutations passed in a bacterial cell?
   ANS: Because bacteria are single cells and reproduce asexually, all genetic mutations are passed to offspring.

4. How do researchers think staph acquired resistance to vancomycin?
   ANS: Researchers believe staph acquired resistance through horizontal gene transfer with Enterococcus because of their proximity in wounds.

5. How can gene flow cause evolution?
   ANS: Gene flow is the exchange of alleles between populations and can occur between two different species or between two populations of the same species. If the transferred alleles are advantageous, they will be incorporated into the genome, thus causing allele frequency shifts and evolution.

SECTION 4: PRIMED FOR PICKUP
Key scientific topics covered:
• Genetic drift as a mechanism for evolution
• Genetic bottleneck and founder effect
• Genetic bottleneck as a type of genetic shift

Road Blocks
• Many students do not understand what an antibiotic is or its points of origin. Correcting their misconceptions of antibiotics before beginning this section may prove to be helpful.

Check Your Understanding Questions
1. Why might an organism exhibit a phenotype that decreases its chance of survival?
   ANS: In sexual selection, nature selects the traits that increase the chances of mating even if the chance of survival is decreased.
2. Give an example of an organism that exhibits sexual dimorphism and describe the differences between the sexes.

ANS: Answers may include that some male birds perform elaborate mating displays, but females do not; male lions have a mane, but females do not; and so forth.

3. The CC5 staph is vancomycin resistant. What three mechanisms of evolution are attributed to the resistance?

ANS: Mutation, natural selection, and gene flow.

4. Genetic drift does not necessarily favor those better suited for their environment. Instead, it’s the “lucky” individuals that pass on their traits to the next generation. What kinds of populations are more susceptible to this mechanism for evolution?

ANS: Small populations are more likely to be impacted than large ones.

5. There are two types of genetic drift: genetic bottleneck and founder effect. What are the similarities and differences between the two?

ANS: Genetic bottleneck is a drop in the size of a population for at least one generation that causes a loss of genetic variation. Generally, the population rebounds, but with less genetic diversity. The founder effect occurs when a small group of individuals establishes a new population isolated from the original. The descendants from this new population tend to have less genetic diversity.

SECTION 5: SEX AND SELECTION
Key scientific topics covered:
• Sexual selection as a mechanism for evolution
• Sexual dimorphism

Check Your Understanding Question
1. Should we continue to be concerned with VRSA since it is not widespread like MRSA? Why or why not?

ANS: Yes, we should still be concerned because although VRSA does not handle the resistance gene from Enterococcus very well, bacteria evolve quickly and may overcome this factor.
# Sample lecture for a 55-minute class

<table>
<thead>
<tr>
<th>TIME</th>
<th>HOMEWORK</th>
<th>LECTURE</th>
<th>ACTIVITY</th>
<th>LEARNING OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Class period 1</strong></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Read the introduction to Chapter 12 and the section “Birth of a Superbug.” Complete the InQuizitive adaptive Chapter 12 assignment.</td>
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</tr>
<tr>
<td>10 min.</td>
<td>Define evolution and descent with modification.</td>
<td></td>
<td>12.1 Clarify why evolution occurs only in populations, not in individuals.</td>
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</tr>
<tr>
<td>5 min.</td>
<td>Show the Biology Now animation “Horizontal Gene Transfer.”</td>
<td></td>
<td>12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.</td>
<td></td>
</tr>
<tr>
<td>15 min.</td>
<td>Discuss four mechanisms of evolution.</td>
<td></td>
<td>12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.</td>
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<tr>
<td>10 min.</td>
<td>Wrap up with clicker questions or quiz.</td>
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<tr>
<td></td>
<td><strong>Class period 2</strong></td>
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<tr>
<td>10 min.</td>
<td>Read the Chapter 12 sections “Rising Resistance” and “Enter Enterococcus.”</td>
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<tr>
<td>10 min.</td>
<td>Show Ultimate Guide video “Dogs versus Hyenas” and discuss convergent evolution.</td>
<td></td>
<td>12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.</td>
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</tr>
<tr>
<td>10 min.</td>
<td>Give a quiz on directional, disruptive, and other selections.</td>
<td></td>
<td>12.2 Distinguish among directional, stabilizing, and disruptive selection.</td>
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</tr>
<tr>
<td>10 min.</td>
<td>Have students do the Ultimate Guide activity “The Evolution of Echolocation in Bats and Whales.”</td>
<td></td>
<td>12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.</td>
<td></td>
</tr>
<tr>
<td>5 min.</td>
<td>Discuss gene flow in prokaryotes and eukaryotes.</td>
<td></td>
<td>12.6 Explain how gene flow works and how it may inhibit evolution.</td>
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</tr>
</tbody>
</table>
### Sample lecture for a 55-minute class (continued)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>20 min.</td>
<td></td>
<td>Show the <em>Ultimate Guide</em> video “The Making of the Fittest: Natural Selection in Humans,” then use discussion questions.</td>
<td>12.5 Describe how DNA mutations can create new alleles at random.</td>
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</table>

#### Class period 3

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Read the Chapter 12 sections “Primed for Pickup” and “After Vancomycin.” Answer review questions at the end of the chapter.</td>
<td>Give a quiz on genetic drift and genetic bottlenecks.</td>
<td>12.7 Relate the process of genetic drift to genetic bottlenecks and the founder effect, using examples.</td>
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<tr>
<td>10 min.</td>
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<td></td>
<td>12.2 Distinguish among directional, stabilizing, and disruptive selection.</td>
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<tr>
<td>30 min.</td>
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<td>Wrap up with the <em>Ultimate Guide</em> activity “Mechanisms of Evolution Concept Map.”</td>
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<tr>
<td>15 min.</td>
<td>Complete the Smartwork5 Chapter 12 assignment.</td>
<td>Review or start new chapter.</td>
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</tbody>
</table>
**Sample lecture for a 90-minute class**

<table>
<thead>
<tr>
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<td>10 min.</td>
<td>Define evolution and descent with modification.</td>
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<td>12.1 Clarify why evolution occurs only in populations, not in individuals</td>
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<tr>
<td>15 min.</td>
<td>Show the <em>Biology Now</em> animation “Horizontal Gene Transfer.”</td>
<td></td>
<td>12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.</td>
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<tr>
<td>15 min.</td>
<td>Discuss four mechanisms for evolution.</td>
<td></td>
<td>12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.</td>
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<tr>
<td>5 min.</td>
<td>Break</td>
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<tr>
<td>10 min.</td>
<td>Show the <em>Ultimate Guide</em> video “Dogs versus Hyenas,” then discuss convergent evolution.</td>
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<td>12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.</td>
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<td>Give a quiz on directional, disruptive, and other selections.</td>
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<td>12.2 Distinguish among directional, stabilizing, and disruptive selection.</td>
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<tr>
<td>10 min.</td>
<td>Have students complete the <em>Ultimate Guide</em> activity “The Evolution of Echolocation in Bats and Whales.”</td>
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<td>12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.</td>
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<td><strong>Class period 2</strong></td>
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<tr>
<td></td>
<td>Read the Chapter 12 sections “Enter Enterococcus,” “Primed for Pickup,” and “After Vancomycin.” Answer review questions at the end of the chapter.</td>
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</tbody>
</table>
### Sample lecture for a 90-minute class (continued)

<table>
<thead>
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<tr>
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<td>5 min.</td>
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</tr>
<tr>
<td>20 min.</td>
<td>Complete the Smartwork5 Chapter 12 assignment.</td>
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</table>

Complete the Smartwork5 Chapter 12 assignment.
Animation
Horizontal Gene Transfer

LENGTH: 2 minutes, 5 seconds

LEARNING OBJECTIVES COVERED:
• 12.1 Clarify why evolution occurs only in populations, not in individuals.
• 12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.
• 12.5 Describe how DNA mutations can create new alleles at random.

SUMMARY: This animation depicts the horizontal gene transfer of plasmid DNA through conjugation. A micrograph shows two bacteria connected by a conjugation tube in the process of passing plasmid DNA from one to the other. The example shows a case of Vancomycin Resistant Staphylococcus aureus (VRSA), in which Staphylococcus aureus acquired the vancomycin resistance gene through horizontal gene transfer from Enterococcus.

CLASSROOM USE: This animation may be shown early in the discussion of the Chapter 12 material. It provides a practical example of how evolution via the acquisition of new genes creates genetic diversity. While the animation is easy to understand, students will be best served if they read the chapter introduction and the “Birth of a Superbug” section before viewing the video.

Discussion prompts:
1. Describe a genetic trait you would like to acquire if humans could do horizontal gene transfer with any mammal.
2. Will a donor bacterial cell retain antibiotic resistance following horizontal gene transfer of a plasmid-borne antibiotic resistance allele? Why or why not?

Multimedia Suggestions
The Making of the Fittest: Natural Selection and Adaptation

DIRECTIONS TO VIDEO: Go to the Howard Hughes Medical Institute website (www.hhmi.org) and search for “natural selection and adaptation.” This video is classified as “biointeractive.”

LENGTH: 10 minutes, 25 seconds

LEARNING OBJECTIVES COVERED:
• 12.1 Clarify why evolution occurs only in populations, not in individuals.
• 12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.
• 12.5 Describe how DNA mutations can create new alleles at random.

SUMMARY: The video illustrates the relationship between mutation and natural selection. It shows how two phenotypes in rock pocket mice are affected by predation in different environments. The results of DNA analysis are used to determine that different mutations lead to the same phenotype in different populations.
Selective advantage and the spread of genes in a population are demonstrated by showing how a 1 percent or 10 percent advantage can quickly change the genetic makeup of a population. The video addresses the misconception that evolution is random by distinguishing between random mutations and non-random selection.

**CLASSROOM USE:** This video could be used as an introduction to evolution. It shows the interaction of environment and genes in a simple system while addressing common misconceptions about evolution. The video website includes materials for analyzing amino acid data for different phenotypes of rock pocket mice as well as links to other supporting materials.

**Discussion prompts:**
1. Discuss why evolution has no final "end product." Give examples of how a changing environment can alter which trait is adaptive.
2. Explain which parts of the evolutionary process are random and which parts are not random.

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**The Making of the Fittest: Natural Selection in Humans**

**DIRECTIONS TO VIDEO:** Go to the Howard Hughes Medical Institute website (www.hhmi.org) and search for “sickle cell fittest.” This video is classified as "biointeractive" and should be near the top of the list.

**LENGTH:** 14 minutes, 3 seconds

**LEARNING OBJECTIVES COVERED:**
- 12.3 Explain how natural selection brings about increased reproductive success of a population in its environment.
- 12.5 Describe how DNA mutations can create new alleles at random.

**SUMMARY:** The video traces the understanding of the relationship between malaria and the sickle-cell trait through interviews with Tony Allison. He describes his first hypothesis and the experiments that he used to test it. The narration emphasizes that evolution does not find the “best” solution but an available one. The increase in fitness is emphasized.

**CLASSROOM USE:** This video could be used in the classroom to illustrate natural selection of a human trait. It is also a good example of the scientific method. Students could work in small groups to map Allison’s work onto the “observation, hypothesis, experiment, results, conclusion” model of deductive science. The video could also be used to start a discussion of modern human evolution.

**Discussion prompts:**
1. Explain why the harmful trait of sickle-cell disease has not disappeared from the human gene pool, and explain how it might decrease in prevalence in the future.
2. What evidence was used to draw the conclusion that this trait can be adaptive in the heterozygote condition?
Dogs versus Hyenas

**DIRECTIONS TO VIDEO:** Go to YouTube (http://www.youtube.com) and search for “phd dog hyenas.” This video was uploaded by username “Piled Higher and Deeper (PHD Comics).”

**LENGTH:** 2 minutes, 1 second

**LEARNING OBJECTIVES COVERED:**
- 12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.

**SUMMARY:** In this “describe your thesis in two minutes” animation, convergent evolution is concisely explained using the bone-crushing adaptations of dogs and hyenas. This video also shows a different way to analyze bones and fossils to build biomechanical models.

**CLASSROOM USE:** This video could be used as an example during a lecture on convergent evolution. It concisely summarizes the concept and summarizes evidence for convergence. This video also shows a different type of expertise that can be used to study biology.

**Discussion prompts:**
1. What adaptations are necessary for the ability to crush bones in the skull?
2. Hypothesize about the evidence that was used to determine that bone-crushing adaptations are an example of convergent evolution rather than of a single evolutionary lineage.

**In the Lab**

Use Lab 13 in the second edition of *Discovering Biology in the Lab* to apply concepts covered in Chapter 12.
Mechanisms of Evolution Concept Map

**TYPE:** Group active learning exercise

**TOPIC:** Mechanisms of evolution

**TIME IN CLASS:** 20–30 minutes

**CLASSROOM TYPE:** Lecture hall or seminar

**LEARNING OBJECTIVES COVERED:**
- 12.2 Distinguish among directional, stabilizing, and disruptive selection.
- 12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.
- 12.5 Describe how DNA mutations can create new alleles at random.
- 12.6 Explain how gene flow works and how it may inhibit evolution.
- 12.7 Relate the process of genetic drift to genetic bottlenecks and the founder effect, using examples.

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**Materials**
One handout per group of 3 or 4 students, one 8.5" × 11" sheet of paper per group

**Topic Level**
Students should have read the chapter regarding mechanisms of evolution and be familiar with the basic terminology presented in the reading.

**Classroom Procedure**
Divide students into groups of three or four. Distribute the handout and one blank sheet of paper to each group of students.

Explain to students that a concept map is a tool intended to help them demonstrate how concepts/terms are related to each other, and explain how it can be used as a study/learning aid to understand those relationships. The concepts/terms on the handout will be placed in "bubbles," then the appropriate definition or action will be selected and written on a line leading to the bubble from a related concept. Students may feel the need to add some terms such as "genes" or "existing alleles"; they should be encouraged to do so, as this shows their understanding of how those terms relate to the others.

Give groups roughly 10 minutes to work together to construct their concept map. Check on groups during this time; this will give you the opportunity to ascertain student understanding. You do not have to give them enough time to completely finish the map.

Once you think the class is ready and before the students get off topic, call the class back together. Select one of the groups to put its map on the board for the whole class, and ask for constructive comments from the class.

**Extension**
This activity can be extended by including additional related concepts, definitions, and the overmapping of examples.

**Reflection/Follow-Up**
Discuss with the class how they would map the evolution of VRSA onto the concept map created by the class. Are there concepts involved in the evolution of VRSA that do not appear on the class map? How/where would those concepts fit into the class map?
Mechanisms of Evolution
Concept Map

Use the concepts in the left-hand column for the “bubbles” on your concept map. Use the definitions in the right-hand column for the map lines leading to the bubbles. Remember to arrange the bubbles in a way that shows how they may relate to each other. Note: the definitions and terms are not aligned with each other below; you will need to determine which definition matches which concept.

<table>
<thead>
<tr>
<th>BUBBLES/CONCEPTS</th>
<th>ACTION/DEFINITION LINES CONNECTING BUBBLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional selection</td>
<td>A reduction in population size leads to loss of genetic variation in the new population.</td>
</tr>
<tr>
<td>Stabilizing selection</td>
<td>A few individuals from a large population establish a new population with less genetic variation than the original population.</td>
</tr>
<tr>
<td>Disruptive selection</td>
<td>Allele frequencies change due to random events.</td>
</tr>
<tr>
<td>Convergent evolution</td>
<td>One phenotypic extreme has an advantage over all others in the population.</td>
</tr>
<tr>
<td>New alleles</td>
<td>Intermediate phenotypes have an advantage over all others in the population.</td>
</tr>
<tr>
<td>Evolution</td>
<td>Both phenotypic extremes have an advantage over the intermediate phenotypes.</td>
</tr>
<tr>
<td>Sexual selection</td>
<td>Distantly related organisms evolve similar structures in response to similar environmental challenges.</td>
</tr>
<tr>
<td>Gene flow</td>
<td>Created by mutations.</td>
</tr>
<tr>
<td>Genetic drift</td>
<td>Change in allele frequencies in a population over time.</td>
</tr>
<tr>
<td>Genetic bottleneck</td>
<td>A trait increases a particular phenotype’s chance of mating regardless of how it affects the phenotype’s overall chance of survival.</td>
</tr>
<tr>
<td>Founder effect</td>
<td>Alleles are exchanged between populations.</td>
</tr>
</tbody>
</table>
The Evolution of Echolocation in Bats and Whales

TYPE: Think-Write-Share

TOPIC: Interactions of DNA mutation, natural selection, and convergent versus divergent evolution

TIME IN CLASS: 10 minutes

CLASSROOM TYPE: Lecture hall or seminar

LEARNING OBJECTIVES COVERED:
■ 12.4 Compare and contrast convergent evolution and evolution by common descent, and give an example of each.

Material
One copy of the handout per student

Topic Level
Students should be familiar with the topics of gene mutation, natural selection, and convergent versus divergent evolution.

Classroom Procedure
Pose the question at the top of the handout to students. Individually, students should reflect on the question and write down their responses (allow 1–2 minutes).

Students can then form pairs and discuss their responses in order to reach a consensus decision. Afterward, have pairs share their responses with the entire class and discuss.

Extensions
This activity can be extended by assigning the following reading(s) from ScienceDaily (http://www.sciencedaily.com), to be completed before the next class period:
■ “In Bats and Whales, Convergence in Echolocation Ability Runs Deep” (posted January 27, 2010)
■ “Genetic Similarities between Bats and Dolphins Discovered” (posted September 4, 2013)

Upon returning to class, students should consider the following: “After reading the assigned articles, state whether you have an alternate hypothesis regarding the evolution of echolocation in bats, dolphins, and whales. Support your hypothesis with information regarding the genetic basis for echolocation.”

Students (or pairs) can be asked to share their hypothesis with the class.

Reflection/Follow-Up
This activity provides students the opportunity to apply their knowledge on a higher level by asking them to generate a hypothesis, revise their existing hypothesis, or synthesize a new one in light of new information.

Answer Key
Students should realize the evolution of echolocation is still considered convergent evolution, but the gene mutations leading to it run deep in the evolutionary time line.
The Evolution of Echolocation in Bats and Whales

Convergent evolution is typically viewed as representing alternate evolutionary solutions (to selective pressure) involving different sets of genes in organisms that are not closely related. Do you think this is the case for the evolution of echolocation in bats (flying mammals) and cetacean mammals (dolphins and whales)? Why?

After discussing this question as a class, what additional information would you add to your answer?

Activity Extension
Read one or both of these articles from ScienceDaily (www.sciencedaily.com).

- “In Bats and Whales, Convergence in Echolocation Ability Runs Deep” (posted January 27, 2010)
- “Genetic Similarities between Bats and Dolphins Discovered” (posted September 4, 2013)

After reading the assigned articles, state whether you have an alternate hypothesis regarding the evolution of echolocation in bats, dolphins, and whales. Support your hypothesis with information regarding the genetic basis for echolocation.
Reading Quiz

QUESTION 1
A particular gene in a population has two alleles, C and c. If the allele frequency of C = 0.7, what is the frequency of c?
- a. 0.3
- b. 0.7
- c. 1.0
- d. 0.0

QUESTION 2
A population experiencing a genetic bottleneck would have which of the following characteristics?
- a. Sexual selection
- b. High levels of gene flow
- c. High mutation rates
- d. Small population size

QUESTION 3
A species of bird lives in an area where large and small seeds are common, but medium size seeds are not. Birds with large beaks are adept at eating large seeds and birds with small beaks are adept at eating small seeds. This population will likely undergo
- a. Stabilizing selection
- b. Directional selection
- c. Disruptive selection
- d. Artificial selection

QUESTION 4
A storm kills all of the plants on a hillside; the rest of the population is unharmed. The allele frequency of the alleles seen in the plants that do not live on the hill increases. This is an example of
- a. Genetic drift
- b. Natural selection
- c. Gene flow
- d. The founder effect

QUESTION 5
A tourist brings home a small fish and releases it into a nearby lake. This fish is able to breed with fish already in the lake. The lake population is mainly orange and this fish is white. This is an example of
- a. The founder effect
- b. Gene flow
- c. A bottleneck
- d. Genetic drift

QUESTION 6
A tourist carries home a handful of seeds collected during a hiking trip. This species does not exist in the tourist’s home area. These seeds germinate in the
tourist’s home area and establish a new population with traits that are uncommon in the plant’s native area. This is an example of
a. A bottleneck
b. The founder effect
c. Gene flow
d. Artificial selection

QUESTION 7
An example of analogous traits are
a. Human arms and human legs
b. Bat wings and whale fins
c. Bat wings and bird wings
d. Human arms and chicken wings

QUESTION 8
Consider a mouse population with a total of 500 alleles for a specific gene. How many individuals are in this population?
a. 250
b. 500
c. 1,000
d. 125

QUESTION 9
During horizontal gene transfer, a bacterium passes DNA to the recipient through a connection called a
a. Conjugation tube
b. Chromosome
c. Plasmid
d. Gene flow tunnel

QUESTION 10
Several generations into the future, a population of birds currently undergoing stabilizing selection will look
a. More like one of the extremes
b. More like both of the extremes
c. More like the current mean
d. Less like the current mean

QUESTION 11
Sexual selection in a population
a. Does not lead to evolution
b. Always favors individuals with a higher survival potential
c. Can lead to physical differences between males and females of a species
d. Reduces genetic variation in the population

QUESTION 12
The evolutionary effects of genetic drift are
a. Always the same as those of natural selection
b. Usually random and unpredictable
c. Most obvious in large populations
d. Shaped by nonrandom selective forces
**QUESTION 13**
The genetic mutations that occur in organisms are
a. The raw material of evolution
b. Relatively rare events that have little consequence for evolution
c. Directed toward a particular adaptive goal
d. Predictable by scientists before they actually occur

**QUESTION 14**
The population of crayfish on the left represents a population that is
a. drastically reduced in size by a natural disaster.
b. reproductively isolated from all other populations.
c. maintaining the same color frequencies over time.
d. changing its allele frequencies due to the founder effect.

**QUESTION 15**
Watch the animation “Horizontal Gene Transfer” and then answer the question below.
It seems that vancomycin-resistant S. Aureus (VRSA) acquired the resistance gene
a. through sexual reproduction.
b. through mutation in the chromosomal DNA.
c. by receiving plasmid DNA from another species of bacteria.
d. when a genetic bottleneck killed most members of a non-resistant population.

**QUESTION 16**

What does the following analogy demonstrate?

a. Only organisms with the yellow trait survive.
b. The purple organisms mutate to become yellow.
c. Only organisms with the purple trait survive.
d. The yellow organisms mutate to become purple.

**QUESTION 17**
What is the allele frequency of the white-fur-pigment allele?

a. 5/15, or 1/3  
b. 15/30, or 1/2  
c. 10/15, or 2/3  
d. 13/30

**QUESTION 18**
Which of the following is more likely to occur when a population of organisms is small?

a. Mutation  
b. Natural selection  
c. Random mating  
d. Genetic drift

**QUESTION 19**
Which of the following is NOT a correct statement regarding the evolutionary process?

a. Inheritable characteristics are produced by random genetic events, such as mutation  
b. Allele frequencies in an individual change over time  
c. Natural selection acts on the genetic variation present in a population  
d. Random mutations and genetic rearrangements occur

**QUESTION 20**
Which of the following should you avoid to limit the spread of antibiotic resistance among pathogenic bacteria?

a. Saving leftover antibiotics to take for your next illness  
b. Good hygiene and sanitation  
c. Taking the full course of an antibiotic when it is prescribed  
d. Getting vaccinated

**QUESTION 21**
Which of the following statements about gene flow is true?

a. It rarely occurs in natural populations  
b. It reduces the genetic variation within a single population  
c. It reduces the genetic variation between different populations  
d. It reduces the movement of alleles between populations

**QUESTION 22**
Which of the following statements about genetic variation is true?

a. The only source of genetic variation is gene transfer  
b. New alleles are only formed during sexual reproduction  
c. Mutation is the ultimate source of new alleles  
d. Mutations that occur in skin cells can be inherited
Infographic Questions

Race against Resistance

*Each year in the United States, more than 2 million people become infected with antibiotic-resistant bacteria, including methicillin-resistant Staphylococcus aureus (MRSA), resulting in at least 23,000 deaths. To combat antibiotic resistance, doctors need novel antibiotics, yet fewer new antibiotics come to pharmacies each year. In 2011, Congress passed the Generating Antibiotic Incentives Now (GAIN) Act to stimulate the development of new antibiotics, and it’s working. So far, six new antibiotics have been approved through that program.

Antibacterial drugs approved by the FDA

Assessment available in smartwerk5.

Time line of antibiotic resistance


Tetracycline
Enthromycin
Methicillin
Gentamicin
Vancomycin
Ceftriaxone
Imipenem
Levofoxacin
Linezolid
Ceftizoxime
QUESTION 1
Use the following infographic image to answer the questions below. Click to view larger image.

Which antibiotic existed the longest before bacteria resistant to it were identified?
- a. Tetracycline
- b. Vancomycin
- c. Ceftazidime
- d. Levofloxacin

QUESTION 2
How long did it take for the first gentamicin-resistant bacteria to be identified after its introduction?
- a. 2 years
- b. 12 years
- c. 17 years
- d. less than 1 year

QUESTION 3
During which time period were the greatest number of antibiotics introduced?
- b. 2000–2015
- c. 1995–2009
The Basics

1. The founder effect is a type of (genetic drift / gene flow) in which individuals in one small group of a large population (establish a new distant population / are the only survivors) and then reproduce.

2. Unlike natural selection, ______________ is not related to an individual’s ability to survive and may result in offspring that are less well adapted to survive in a particular environment.
   a. Genetic drift
   b. Sexual selection
   c. Directional selection
   d. Convergent evolution

3. Which of the following statements about convergent evolution is true?
   a. It demonstrates how similar environments can lead to different physical structures.
   b. It demonstrates how similar environments can lead to the same physical structures.
   c. It demonstrates that similarity of structures is due to descent from a common ancestor.
   d. It demonstrates that similarity of structures is due to random change.

4. Evolution is most accurately described as a change in allele frequencies in __________ over time.
   a. An individual
   b. A species
   c. A population
   d. A community

Answers

Answers To Reading Quiz

1. A
2. D
3. C
4. A
5. B
6. B
7. C
8. A
9. A
10. C
11. C
12. B
13. A
14. C
15. C
16. C
Answers To Infographic Questions

1. B
2. B
3. A

Answers To The Basics

1. genetic drift, establish a new distant population
2. b
3. b
4. c

Answers To Figure Questions

Figure 12.2
Q1: What is natural selection selecting for here?
A1: Methicillin-resistant S. aureus (MRSA).

Q2: Why do bacteria that are not genetically resistant to antibiotics die out when exposed to antibiotics?
A2: After entering a bacterium, an antibiotic generally blocks or poisons one or more processes of the bacterium’s life cycle so that it cannot survive or reproduce. Bacteria that have a mechanism to pump out the poison generally survive the poison and live to reproduce; they are termed “resistant.”

Q3: Why is the antibiotic represented by a kitchen strainer in this figure?
A3: The antibiotic is depicted as a kitchen strainer because antibiotics act like strainers: they can “catch” or kill most bacteria in a population, but there will always be at least one bacterium that can survive the antibiotic assault and slip through the strainer.

Figure 12.4
Q1: What is the difference between MRSA and VRSA?
A1: Both of these bacteria are members of the species Staphylococcus aureus. The species name is the “SA” part of both names. The “MR” in MRSA stands for “mecillin-resistant,” and the “VR” in VRSA stands for “vancomycin-resistant.” The only difference between these two populations is that MRSA survives in the presence of the antibiotic mecillin but can be killed by vancomycin, while VRSA survives in the presence of both mecillin and vancomycin.

Q2: Why is there a clear zone (the “zone of inhibition”) around the paper disk in the top dish but not in the bottom dish?
A2: The clear zone represents the area where the antibiotic has seeped into the medium from the antibiotic-soaked paper disk and killed off the bacteria. The bacteria cannot grow here, so all you see is the growth medium in the dish, with no bacteria growing on it. The rest of the dish is covered by bacteria and appears opaque.

Q3: Why is the lack of a clear zone around the paper disk in the bottom dish so alarming?
A3: The lack of a clear zone in the bottom dish suggests that the antibiotic of last resort, vancomycin, cannot kill the bacteria and they grow just as well in the antibiotic area as in the areas away from the vancomycin-soaked paper disk. If the last-resort antibiotic doesn’t kill these bacteria, there is no current antibiotic that will. VRSA is a deadly bacterial infection against which we have no good defense.

Figure 12.5
Q1: What would the white-fur-pigment allele frequency be if three of the homozygous black allele mice (having two black alleles) were heterozygous (having one white and one black allele) instead?
A1: 16/30 = 53%.

Q2: What would the white-fur-pigment allele frequency be if all of the white mice died and were therefore removed from the population? Would the black-fur-pigment allele frequency be affected? If so, how?
A2: The white-fur-pigment allele frequency would be 3/20 = 15%. Yes, the black-fur-pigment allele frequency would be affected; there would then be 17 black alleles out of a total of only 20 alleles: 17/20 = 85%.

Q3: What would the white-fur-pigment allele frequency be if all of the gray mice died and were therefore removed from the population?
A3: 10/10 = 100%.

Figure 12.6
Q1: Why does the population of S. aureus bacteria not pose a life-or-death health threat outright?
A1: These are the bacteria that normally live on our skin and do not harm us unless there is a major skin disturbance like a burn or a large scrape that is not cleaned and kept protected.

Q2: Why do vancomycin-resistant bacteria have a higher frequency in the population after treatment with vancomycin?
A2: All of the bacteria that do not contain the resistance allele are killed by the vancomycin and therefore no longer exist. The only bacteria left are the vancomycin-resistant bacteria (VRSA).

Q3: If this figure used the mouse example of allele frequency from Figure 12.5, and the white mice increased in numbers like the vancomycin-resistant bacteria here did, what would happen to the frequencies of the white-fur-pigment and black-fur-pigment alleles?
A3: The white-fur-pigment allele would increase in frequency, and the black-fur-pigment allele would decrease in frequency.
Figure 12.7
Q1: If one extreme phenotype makes up most of a population after directional selection, what happened to the individuals with the other phenotypes?
A1: They were killed and eaten by predators.
Q2: What do you think would happen to the phenotypes of the peppered moth if the tree bark was significantly darkened again by disease or pollution?
A2: Since the moths that survive are more similar to the color of the bark and thus are protected from birds, which cannot as easily see them to kill and eat them, the phenotype of the population of peppered moths would become darker like the trees.
Q3: What do you think would happen to the phenotypes of the peppered moth if the tree bark became a medium color, neither light nor dark? (You will need to read the next paragraph to answer this question.)
A3: Stabilizing selection would likely occur, and only medium-colored moths would not be killed and eaten by birds.

Figure 12.8
Q1: Think of another example of stabilizing selection in human biology. Has modern technology or medicine changed its impact on the resulting phenotypes?
A1: Stabilizing selection probably affected many human traits before modern technology and medicine played a major role in survival and quality of life. Examples include adult height and weight, which would be affected by many hormone levels and overall metabolism.
Q2: How do you think a graph of birth weight versus survival for a developing country with little health care would compare to the graph shown here?
A2: This graph would be even sharper, with less survival at either end. Evolution would be more stabilizing than in the example shown here.
Q3: How do you think a graph of birth weight versus survival for an affluent city in the United States today would compare to the graph shown here?
A3: This graph would be much wider, with more survival at both ends. Evolution would be much less stabilizing than in the example shown here.

Figure 12.9
Q1: Almost all birds starved during the dry season are depicted here. What type of selection would have been present if only the intermediate-beaked birds had survived (instead of the small- and large-beaked birds)?
A1: Stabilizing selection.
Q2: Describe a scenario in which African seed crackers would experience directional selection for either smaller- or larger-beaked birds. What kind of environmental conditions might bring about such a situation?
A2: If only small seeds were produced in a particular year, then only small-beaked birds would survive and the population would evolve toward smaller beaks. Similarly, if only large seeds were produced, then only large-beaked birds would survive and the population would evolve.
toward larger beaks. An environmental condition that might bring about smaller seeds would be a situation in which the faster germination time of smaller seeds was an advantage—for example, a very brief growing period. A condition that might favor larger seeds would be a situation in which the greater resources contained in the seed would allow it to survive longer—for example, an extended drought.

Q3: Of the three patterns of natural selection presented in this discussion, which one always results in two different phenotypes in the following generations?
A3: Disruptive selection.

Figure 12.10
Q1: How is convergent evolution different from evolution by common descent?
A1: Convergent evolution is essentially the opposite of evolution by common descent. Convergent evolution begins with two distantly related organisms that, over many generations, end up with similar phenotypes because they have adapted to similar environments. Evolution by common descent begins with an original common ancestor and, over many generations, may split into many different populations that are phenotypically different.

Q2: What is the main difference between a homologous trait (see Figure 11.11) and an analogous trait?
A2: A homologous trait is shared between organisms because a common ancestor had that trait; an analogous trait performs a similar function in different organisms but is not shared by a common ancestor. Analogous traits form through convergent evolution.

Q3: Why are convergent traits considered evidence for evolution (see Chapter 11)?
A3: Convergent traits occur through changes in allele frequencies over time—essentially the definition of evolution. Convergent evolution results in organisms that are better adapted to their environment—again, evolution.

Figure 12.13
Q1: If a goose with genotype AA had migrated instead of the goose with genotype aa, would the scenario described here still be considered gene flow? Why or why not?
A1: No, this is technically not gene flow. Although alleles are being exchanged, they are the same as the existing alleles in the population and will not change allele frequencies over time and many generations.

Q2: If a goose with genotype Aa had migrated instead of the goose with genotype aa, would the scenario still be considered gene flow? Why or why not?
A2: Yes, this is gene flow. Although the effect is not as extreme as with the aa genotype, the Aa genotype introduces a new allele into an existing population, creating offspring that can be Aa, and thereby changing allele frequencies over time and many generations.
Q3: If the goose with genotype aa had migrated to population 2 as shown but had failed to mate with any of the AA individuals, would the scenario still be considered gene flow? Why or why not?
A3: No, this is not gene flow. Just adding an individual with different alleles to a population does not count as gene flow. There must be an exchange of alleles between the newcomer and an existing individual.

Figure 12.14
Q1: Why do you think a genetic bottleneck is more likely to occur in a small population than in a large population?
A1: In a large population, it is less likely that a chance event can kill off almost all of the individuals, leaving only a few behind that randomly represent only one of multiple phenotypes. In a small population, a tsunami, hurricane, volcanic eruption, or other natural disaster could easily kill off all but a few individuals. All subsequent offspring would arise from these few individuals, whatever phenotype they might have, regardless of which phenotypes in the original population were best adapted.
Q2: Genetic drift is often described as a “chance event.” Give other examples of chance events that could cause a genetic bottleneck.
A2: Examples that could cause a genetic bottleneck include deadly viruses, famine, drought, immigration of many predators, habitat loss, tsunami, or other natural disaster.
Q3: Which resulting population has more genetic diversity?
A3: The population on the left.

Answers To End-Of-Chapter Questions
1. b
2. b
3. An individual that survives well but is unattractive to potential mates or is unable to compete for access to mates will not reproduce and will not pass on genes.
4. Gene flow is the most likely mechanism because mutations are random, natural selection would have caused populations in different environments to diverge, and genetic drift is most relevant for small populations.
5. Population bottlenecks cause individuals in the resulting population to be more genetically similar to each other. In this case, the two individuals are so similar that each individual does not distinguish another devil’s cells as different from its own cells.
6. b
7. b
Leveling Up Grading Rubrics

8. What do you think?

One way to prevent a small population of a plant or animal species from going extinct is to deliberately introduce some individuals from a large population of the same species into the smaller population. In terms of the evolutionary mechanisms discussed in this chapter, what are the potential benefits and drawbacks of transferring individuals from one population to another? Do you think biologists and concerned citizens should take such actions?

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<td>Excellent</td>
<td>Major benefits and drawbacks of transferring individuals are thoroughly and accurately described.</td>
<td>Opinion is thoughtful, clear, and well supported by data and/or logic.</td>
<td>Writing style is clear and concise and flows well. Perfect or close-to-perfect spelling, grammar, and language usage.</td>
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<td>Opinion is clear, and supported by data and/or logic. Argument may contain some weaknesses.</td>
<td>Clearly written, with only a few errors in spelling, grammar, and language usage.</td>
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<td>Flawed</td>
<td>Description of major benefits and drawbacks of transferring individuals is very incomplete, contains major errors, or is very unclear.</td>
<td>Opinion is not well supported by logic, or argument is unclear.</td>
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<td>Deficient</td>
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<td>Opinion is not supported at all or is completely unintelligible.</td>
<td>Writing is difficult to follow. Serious difficulties with misspelling, errors in grammar, and misuse of language.</td>
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9. Write Now biology: mechanisms of evolution

This assignment explores the mechanisms of evolution through five selected short stories from *Welcome to the Monkey House* by Kurt Vonnegut. Answer the questions associated with each story.

**“Harrison Bergeron”**

What message is this story trying to send? Cite examples from the story and relate them to the mechanisms of evolution from this chapter.

**“Welcome to the Monkey House”**

Is this story an example of sexual selection? Why or why not? Cite examples from the story and from this chapter to support your thinking.

**“The Euphio Question”**

If technology could produce such an instrument, how would it affect the evolution of humans? What about the evolution of other species on Earth?

**“Unready to Wear”**

Relate this story to as many of the mechanisms of evolution from this chapter as you can. Cite examples from the story and the chapter to support your thinking.

**“Tomorrow and Tomorrow and Tomorrow”**

Do you think these types of drugs are a good or bad thing? Where would you draw the line on technology’s ability to extend life? How would drugs like these affect the natural selection and evolution of humans? What about the evolution of other species on Earth?

*See grading rubric on following page.*
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Answers to Thinking Multidimensionally Questions

Extensions to Thinking Multidimensionally questions are included in handouts on the pages following.

10. *This question requires outside research.*

   a. Variation exists within all populations, including giraffe populations. Some giraffes will naturally have slightly longer necks than other giraffes. The giraffes “best fit to the environment” would be better able to reach the leaves on taller tree branches and be more likely to survive and reproduce. In time, the population would be made up of giraffes with necks that are longer than those of their predecessors.

   b. The neck of a giraffe is the most powerful part of its body. The males use them like swords to establish dominance and to win the right to mate with female giraffes.

*Question Extension*

   c. Students should draw an athletic baby with a muscular body.

Next Generation Science Standards

DCI: HS-LS2.D: Social Interactions and Group Behavior

CCC: Cause and Effect, Structure and Function, & Stability and Change

SEP: Constructing Explanations and Designing Solutions, Engaging in Argument from Evidence, & Obtaining, Evaluating, and Communicating Information

11. *This question requires outside research.*

   a. The setup of the experiment was not indicative of what occurs in nature. Moths rarely rest on tree trunks with their wings extended, but the ones used in this experiment were dead and pinned to the trunks as easy targets for birds. In addition, moths do not group together in high densities, yet multiple moth carcasses were pinned to the same trees.

   b. Moths are nocturnal, while most birds are diurnal; they are temporally separated and rarely interact.

   c. Bats use echolocation to hunt their prey; visual cues like wing color variation in moths would not be easily discerned at night.

*Question Extension*

   d. For the years depicted, the nonmelanic (peppered) moths had greater survival rates compared with the melanic forms, except for one year. Air quality is much better today than during the industrial revolution, so this graph supports Kettlewell’s conclusion.

Next Generation Science Standards

DCI: HS-LS4.B: Natural Selection

CCC: Patterns, Cause and Effect, Systems and System Models, & Stability and Change

SEP: Asking Questions and Defining Problems Analyzing and Interpreting Data, Constructing Explanations and Designing Solutions, & Engaging in Arguments from Evidence
10. In 1801, Jean Baptiste Lamarck proposed a mechanism for evolution, the theory of inheritance of acquired characteristics—if an organism changes during its lifetime, those changes are passed on to the progeny. For example, Lamarck thought that giraffes evolved long necks by stretching to reach leaves on tall trees and then passed this new trait on to their offspring.

a. How would Darwin explain how giraffes got long necks?

b. We know that young male giraffes spar with their long necks. Based on your understanding of sexual selection, what is another reason why giraffes may have evolved long necks? What are the costs and benefits of the evolution of this aggressive behavior?

Question Extension
Go to the Understanding Evolution website and read the article “Early Concepts of Evolution: Jean Baptiste Lamarck” (https://evolution.berkeley.edu/evolibrary/article/history_09).

c. Draw what a newborn baby of the WWE wrestling superstar John Cena would look like according to Lamarck.
11. One of the most cited examples of natural selection in biology textbooks is the changes Bernard Kettlewell reported on moth coloration against sooty and lichen-covered tree trunks. In the 1950s Kettlewell pinned dead moths on different tree trunks and observed birds’ feeding preferences. The above figure describes this classic account of evolution via directional selection.

a. Some critics argue this example of “evolution in action” is fraudulent. What flaws are evident in this experimental design?
b. Compare when moths are active with when birds are predominantly active.

c. What are the main predators of moths and how do they find their prey?

Question Extension
Beginning in 2001, Michael Majerus, a professor of evolution from the University of Cambridge, designed a new moth experiment to resolve the issues from Kettlewell’s original experiment. For six years, instead of placing moths on tree trunks during the daytime, Majerus released a total of 4,864 light- and dark-colored moths around sunset on the branches of lichen-covered trees with netting and recorded their numbers the following morning.

Read more about Majerus’s experiment in the article “Selective Bird Predation on the Peppered Moth: The Last Experiment of Michael Majerus” on the website of the Royal Society (http://rsbl.royalsocietypublishing.org/content/early/2012/01/27/rsbl.2011.1136).

d. Examine Figure 1 of the article and report on what this modern version of the moth evolution experiment reveals.