PART 2: BIODIVERSITY

UNIT 3: EVOLUTIONARY THEORY AND BIODIVERSITY

Unit 3: Evolutionary Theory and Biodiversity

Specific Learning Outcomes

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

DEFINING EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)
Include: gene pool and genome

SLO: B12-3-01

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students will be familiar with the term *evolution*, but have not previously studied the topic.

TEACHER NOTE

Evolution is the theme that unifies all the different fields of biology. Emphasize to students the links among evolution, biodiversity, DNA, and genetics. Today, the modern synthesis combines Charles Darwin's theory of evolution by natural selection with Mendelian genetics and the findings of population biology. In genetic terms, *evolution* occurs not to individuals, but to populations, and is defined as a change in the allele frequency in a population's gene pool. The fact that evolution occurs in populations (not individuals) must be emphasized.

BACKGROUND INFORMATION

For more information about the nature of science and evolution, refer to Appendix 3.1: Nature of Science—Evolution (Teacher Background).

ACTIVATE

Evolution Survey

Survey students about their prior knowledge of evolution to determine their level of understanding, so that misconceptions can be addressed. Refer to Appendix 3.2A: Evolution Survey (BLM) and Appendix 3.2B: Evolution Survey (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

ACQUIRE/APPLY

Evolution of a Style/Product—Demonstration (U1)

Use pictures or photographs to illustrate the evolution of a style or a product (e.g., hairstyles, clothing, automobiles, telephones).

Pose the following questions:

- Can you explain how the style or product is the same? (It still has the same function.)
- Can you explain how it changed over time? (Answers will vary, depending on the example used.)
- What might have caused the observed changes? (Answers will vary, depending on the example used. Answers may include improved technology, fashion design trends, and so on).
- Organisms also change over time. How is the evolution of organisms different from the evolution of styles or products? (The evolution of organisms is usually much slower.)

Defining Evolution (U2, I1, G1)

Group students into teams and have the teams consult a variety of sources to gather definitions of the term *evolution*. These sources should include print (e.g., textbook, dictionary), electronic (e.g., Internet), and personal resources (e.g., teacher, parent).

Share a biological definition of evolution with the class. Ask the groups to examine the definitions they have gathered, and compare them to the biological definition of evolution, discussing commonalities and differences. Remind students of the distinction between the reality that evolution has occurred (the fact) and the explanation for how evolution occurs (the theory of natural selection).

DEFINING EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-01: Define the term *evolution*, explaining how evolution has led to biodiversity by altering populations and not individuals. (GLOs: D1, E3)

Include: gene pool and genome

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn't know before class today?
- What did you already know?
- What questions do you still have?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

What Is Evolution? (U1)

Provide students with a definition of the term *evolution*. Make the distinction between the fact that evolution has occurred (e.g., fossil evidence, DNA analysis) and the explanation for the mechanism of how evolution occurs (the theory of natural selection). Discuss that evolution occurs not to individuals, but to populations. Evolution is a change in the allele frequency in a population's gene pool.

Resource Links

- Evolution and the Nature of Science Institutes. *ENSIweb*. <www.indiana.edu/~ensiweb/>.
  This website offers a collection of lessons, interactive learning activities, and resources for teaching about the nature of science and evolution.

- The National Science Digital Library (NSDL). Home Page. <http://ndsl.org>.
  The online collections of evolution resources for teachers on this website include lesson plans, videos, interactives, and articles.

- University of California Museum of Paleontology. Home Page. <www.ucmp.berkeley.edu/>.
  This website provides links to online exhibits and educational resources on a range of topics related to evolution, including lessons, articles, modules, and interactives.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

Suggestion for Assessment

At the end of the lesson, pose the following question to students:

- How has your understanding of the term *evolution* changed?

Give students five minutes to respond in their notebooks.

The use of this quick formative assessment tool helps teachers gain information about what students learned in a particular lesson. Responses should indicate students have gained a clearer understanding of the biological definition of *evolution*.

Building Vocabulary (U1)

Introduce new vocabulary to students as required. The use of a variety of strategies (e.g., Word Cycle, Three-Point Approach) can aid students in developing both conceptual and contextual knowledge of the vocabulary of biology. For more information on building a scientific vocabulary and for examples of think-sheet frames, refer to *SYSTH* (Chapter 10).

Suggestion for Assessment

Completed think-sheet frames can be peer assessed or handed in for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, no mark is required. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

THE HISTORICAL CONTEXT

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

SLO: B12-3-02

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

Students have not previously studied this topic, but they may be somewhat familiar with Charles Darwin, evolution, and the concept of "survival of the fittest."

TEACHER NOTE

This learning outcome provides an opportunity to explore the nature of science with students. For example, while Jean Baptiste Lamarck's ideas may seem silly to us today, in his time, he was a well-respected scientist who was one of the first to propose a mechanism explaining how organisms change over time. The fact that his theory was discarded when another theory with a better explanation was proposed is an excellent illustration of how science works.

BACKGROUND INFORMATION

The dynamic nature of the "evolution" of evolution is a vehicle with which to explore the nature of science with students. Contributing scientists include the following:

- **James Hutton** (1726–1797) and **Charles Lyell** (1797–1875) studied the forces of wind, water, earthquakes, and volcanoes. They concluded that the Earth is very old and has changed slowly over time due to natural processes.
- **Erasmus Darwin** (1731–1802) suggested that competition between individuals could lead to changes in species. (He was Charles Darwin's grandfather.)
- **Jean Baptiste Lamarck** (1744–1829) proposed a mechanism by which organisms change over time. He hypothesized that living things evolve through the inheritance of acquired characteristics.
- **Thomas Malthus** (1766–1834) observed that human populations cannot keep growing indefinitely. If the human birth rate continued to exceed the death rate, eventually humans would run out of living space and food. According to Malthus, famine, disease, and war prevented endless population growth.
- **Charles Darwin** (1809–1882) formulated a theory of evolution by natural selection based on observations made during his voyage on the *Beagle*, and of selective breeding of farm animals, plants, and pets. Darwin drafted manuscripts outlining his theory in the 1840s but hesitated to release them to the public. His most famous work *On the Origin of Species by Means of Natural Selection* was published in 1859.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

- **Alfred Russell Wallace** (1823–1913) proposed a theory of evolution by natural selection similar to that of Darwin's theory. He wrote a paper and sent it to Darwin to review. This spurred Darwin on to agree, finally, to the release of his theory. In 1858, Charles Lyell presented Darwin's 1844 essay and Wallace's paper to the public.

ACTIVATE

Setting the Scene—Think-Pair-Share

Pose the following scenario to students:

> *Imagine that you are 21 years old and have just graduated from university. You aren't quite sure whether you want to settle down and start working in your field of study. You have always enjoyed going on hikes and observing nature. One day you see a job advertisement in the paper. The government is looking for people to work on a five-year surveying expedition around the coast of South America. Would you apply for the job? Why or why not?*

Provide students with time to think about and formulate responses to the scenario individually. Students then pair up with a partner to discuss whether they would apply for the job and give reasons for their decisions.

ACQUIRE/APPLY

The Story of Charles Darwin—Article Analysis (U1, N2)

The story of Charles Darwin is a fascinating one. For a brief summary of his life and work, see Appendix 3.3: The Story of Charles Darwin (BLM). Ask students to read the article and complete a Fact-Based Article Analysis Frame (see *SYSTH*, pp. 11.30–11.31, 11.41).

THE HISTORICAL CONTEXT

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

Encourage students to use effective reading strategies to acquire new knowledge from text. This includes activating their prior knowledge before the reading, taking some form of notes during the reading, and discussing/reflecting on what they read. For more information about strategies for reading scientific information, refer to *SYSTH* (Chapter 12).

Suggestion for Assessment

Scan the completed Fact-Based Article Analysis Frames to assess students' understanding. The information gathered can be used to plan further instruction.

Darwin's Process of Discovery (U1)

Use a variety of visuals and multimedia to explain the process of discovery that led Darwin to formulate his theory of evolution by means of natural selection.

The use of a note-taking strategy such as a Note Frame can help students follow a lecture and organize information. For more information, refer to *SYSTH* (p. 11.32).

Resource Links

- The Complete Work of Charles Darwin Online. Home Page. <www.darwin-online.org.uk/>.

  This website contains Darwin's publications, private papers, illustrations, field notebooks, and letters.

- PBS Online. *Evolution*. <www.pbs.org/wgbh/evolution/>.

  The eight-part PBS television series *Evolution* (aired September 2001) addresses a variety of topics related to evolution (including Charles Darwin), extinction, and survival. The series website contains resources for learning about and teaching evolution, an extensive library of print and multimedia resources, web activities, and animations.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Suggestion for Assessment

Note Frames can serve as a useful tool for teachers to monitor students' understanding (formative assessment) and to adjust teaching to address any difficulties. Students can also compare their Note Frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

Evolution Timeline—Research and Presentation (U2, I1, I4, N1)

Have students (individually or in small groups) research a scientist who contributed to the development of a unifying theory explaining how species can change over time.

Students research their assigned scientist and create a poster summarizing the following:

- date of work or publication
- key finding(s)/contribution(s)
- contextual information (e.g., where and when the scientist worked, biographical information on the scientist)

The posters can then be used to create a timeline/flow chart illustrating the development of evolutionary theory. The timeline/flow chart could be displayed in the classroom.

THE HISTORICAL CONTEXT

SPECIFIC LEARNING OUTCOME

B12-3-02: Describe and explain the process of discovery that led Charles Darwin to formulate his theory of evolution by natural selection. (GLOs: A2, A4, B1, B2)

Include: the voyage of the *Beagle*, Darwin's observations of South American fossils, the impact of the Galapagos Islands on his thinking, and the work of other scientists

Resource Link

- The University of California Museum of Paleontology. *Understanding Evolution*. <http://evolution.berkeley.edu/>.

  This website hosts a variety of online exhibits. See "What Is the History of Evolutionary Theories?" in the *Resource Library* for the history of ideas, research, and contributors in the study of evolution.

Suggestions for Assessment

Students prepare and present their research findings and posters to the class.

Create an assessment rubric for the presentations/posters by developing the assessment criteria and performance levels in collaboration with students. The assessment criteria could include

- content
- organization
- visuals

Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Also refer to Appendix 5.8: Checklist for Creating Visuals (BLM).

Postcards from the *Beagle*—Creative Writing Assignment (U2, I1, I4, N1)

RAFTs are creative writing assignments in which students are encouraged to adopt new perspectives on a science concept or issue. For more information, see *SYSTH* (pp. 13.22–13.25). In this learning activity, students assume the persona of Charles Darwin and send home postcards describing their thoughts and observations during the voyage on the HMS *Beagle* (1831–1836). For assignment details, refer to Appendix 3.4: Postcards from the *Beagle*—Creative Writing Assignment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N2: Understand that development and acceptance of scientific evidence, theories, or technologies are affected by many factors. (GLOs: A2, B2)

Examples: cultural and historical context, politics, economics, personalities . . .

Suggestions for Assessment

Create an assessment rubric for the writing assignment by developing the assessment criteria and performance levels in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. Criteria could include biology content, word choice, mechanics, and so on. Alternatively, provide students with strong and weak exemplars of postcards, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

DARWIN'S THEORY

SPECIFIC LEARNING OUTCOME

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

SLO: B12-3-03

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Emphasize that variation in a species is the result of mutations in DNA. These mutations are the source of new alleles, the variations upon which natural selection can act. It is important to remind students that mutations are not goal-directed. They arise randomly in a population, and may produce a change in the structure or function of the organism. Whether the mutation is beneficial or harmful depends on the environment. Evolution then selects for those organisms that are best adapted to their environment at the time.

ACTIVATE

Opening Questions

Pose the following questions to students. Ask them to work in teams to generate responses and have them record their responses in their notebooks.

- Some forms of bacteria can divide by fission as frequently as every 20 minutes in optimal conditions. Assuming we start with one bacterium, how many bacteria could be produced
  - — after one minute? (8)
  - — after two minutes? (64)
  - — after five minutes? (37,268)
  - — after 30 minutes? (1.07×10^9)

Then ask the following question:

- So why aren't we drowning in bacteria?

Possible responses could include the following:

- The bacteria could run out of food.
- The bacteria could run out of oxygen.
- The bacteria could run out of living space.
- Some bacteria could die of old age.
- Some bacteria could be eaten by predators (e.g., white blood cells, mosquito larvae).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Darwin's Theory—Class Discussion (U1)

Engage students in a discussion of their responses to the Opening Questions as an introduction to the main points of Darwin's theory of evolution by natural selection. The main points are summarized below:

- **Overproduction:** More offspring are produced by an organism than can possibly survive.
- **Competition:** High birth rates cause a shortage of life's necessities, leading to competition between organisms.
- **Variation:** Each individual differs from all other members of its species; some differ more than others.
- **Adaptation:** Variations help some organisms to be better suited to their environments than others.
- **Natural selection:** The most fit (best adapted) organisms survive and reproduce.
- **Speciation:** New species form from ancestral species by means of natural selection.

The use of the Three-Point Approach can aid students in developing their understanding of the terminology. For more information about this strategy, refer to *SYSTH* (pp. 10.9–10.10).

Suggestion for Assessment

Students can submit their completed work for teacher feedback. As this learning activity is intended as a formative assessment to check student understanding, no mark is required.

DARWIN'S THEORY

SPECIFIC LEARNING OUTCOME

B12-3-03: Outline the main points of Darwin's theory of evolution by natural selection. (GLO: D1)

Include: overproduction, competition, variation, adaptation, natural selection, and speciation

What Darwin Said (U1)

Use videos and computer animations that illustrate and describe the main points of Darwin's theory to enhance students' conceptual understanding. A wealth of information can be found in a variety of multimedia formats.

Resource Link

- PBS Online. "Evolution." *NOVA beta.* <www.pbs.org/wgbh/nova/beta/evolution/>.

  This website has online *NOVA* television episodes, interactives, and the latest news in evolution science, as well as links to other evolution-related websites and resources.

Suggestion for Assessment

At the end of the lesson, distribute index cards or half sheets of paper. Ask students to describe the "muddiest point" of the lesson—that is, the ideas or parts of the lesson that were confusing or difficult to understand (Gregory, Cameron, and Davies). Let students know you will be using the information to plan the next lesson to benefit them best. At the start of the next lesson, share with students examples of responses that informed your instructional decisions. This will help them realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

Simulating Natural Selection—Laboratory Investigation (U2, S2, S3, S5, I4)

Students investigate natural selection by using different utensils to "capture food." For details, see Appendix 3.5A: Natural Selection Simulation (BLM) and Appendix 3.5B: Natural Selection Simulation (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S2: Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment. (GLOs: B3, B5, C1, C2)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

Assessment of this investigation can be summative (written responses to the questions posed) or formative. The RERUN strategy (Keeley 172–73) can be used for formative assessment of student learning in place of a formal summative lab report.

After students have completed the investigation and answered questions about it, ask them to reflect on their lab experience (individually or in groups) by writing a sentence or two for each letter of the acronym, **RERUN**: **R**ecall (what you did), **E**xplain (why you did it), **R**esults (what you found out), **U**ncertainties (what remains unclear), and **N**ew (what you learned).

ADAPTATION

SPECIFIC LEARNING OUTCOME

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

SLO: B12-3-04

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Adaptation is the result of natural selection. Species that are well adapted to their environments tend to be successful. They survive and reproduce, but again they are not perfect. Should the environment change, many will die, as they are no longer suited to the new environment.

Make a clear distinction between adaptation and acclimatization. *Acclimatization* occurs when an organism becomes accustomed to changing environmental conditions. It is not the product of natural selection. There is no change in the gene pool of the species. For example, when warm spring weather arrives after the cold of winter, we are quick to shed our winter coats and put on shorts and sandals, even though the temperature may be only 10°C. However, should a cold front sweep down from the north in the middle of summer and the temperature fall to 15°C, we would put on jackets and complain about how cold it is. We are acclimatized to the warmer temperatures of summer.

ACTIVATE

Survival of the Fittest—Class Discussion

Provide students with visuals (e.g., overheads, PowerPoint presentations, diagrams, pictures) of organisms with structural, behavioural, or physiological adaptations (e.g., needles on a cactus, canine teeth on a carnivore such as a wolf, seasonal feather colour change in ptarmigans).

Ask students to describe ways in which each organism is well suited to its environment. What special feature does each have that increases its chance of survival or reproduction? What makes the organism fit?

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

What Is an Adaptation? (U1)

With the use of examples, distinguish among behavioural, structural, and physiological adaptations. In the discussion of structural adaptations, include examples of mimicry and camouflage (also known as *cryptic colouration*). For more information about adaptation, see Appendix 3.6: Adaptation (Teacher Background).

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

Suggestion for Assessment

Post the following question on the classroom board so that all students can see it:

- What is an adaptation?

In addition, write the question at the top of a piece of paper and pass it around the class during instruction so that it moves from student to student. Each student must add one or two sentences that relate to the question, and build upon or correct previous student comments.

At the end of the lesson, examine the response chain to assess students' comprehension, and re-teach material if necessary (formative assessment).

ADAPTATION

SPECIFIC LEARNING OUTCOME

B12-3-04: Demonstrate, through examples, what the term *fittest* means in the phrase "survival of the fittest." (GLO: D1)

Examples: stick insects blending with their environment, sunflowers bending toward sunlight, antibiotic-resistant bacteria . . .

Adaptation—Concept Frame (U2)

Graphic organizers assist students in clarifying their thinking and enhance their learning. Have students complete a Concept Frame for the concept of adaptation. Refer to Appendix 1.16: Concept Frame.

Suggestion for Assessment

Assess students' Concept Frames for conceptual understanding and provide descriptive feedback on how they could be improved.

Survival of the Fittest—Demonstrating Understanding (U2)

Pose the following question to students at the end of the lesson:

- With the use of an example, explain what the term *fittest* means in the phrase "survival of the fittest."

Give students five minutes to respond in their notebooks.

Suggestion for Assessment

This learning activity provides a quick formative assessment of what students learned in the lesson. Students' responses should include the following:

- The explanation of the term *fittest* incorporates the use of an example.
- Organisms that are better adapted to their environment are more fit, thereby increasing their chance of survival and successful reproduction.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Adaptation Poster—Research and Presentation (U2, P1, I1, I4)

Students individually research an adaptation in a species of their choice, and present their findings in the form of a poster. The poster should include the following components:

- the name of the species
- a description of the adaptation
- the type of adaptation present (behavioural, physiological, structural)
- an explanation of how the adaptation allows an organism to be better suited to its environment
- a picture, drawing, or diagram of the organism

Suggestions for Assessment

Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals such as posters, collages, graphic organizers, and so on.

Provide students with exemplars of strong and ineffective posters, and have them work in groups to identify possible assessment criteria and define levels of performance for a rubric. The exemplars can be teacher-generated or anonymous samples of student work done in previous years.

Alternatively, assessment criteria can be constructed in collaboration with the class by brainstorming components of the rubric. The criteria could include

- content
- organization
- visuals

Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process.

NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

SLO: B12-3-05

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Caution students against assuming that natural selection and evolution lead to perfection in organisms. Natural selection operates on the variation already present in a species; it cannot create new structures or processes. Regardless of how much time humans spend in the sunlight, for example, we will never be able to manufacture our own food through photosynthesis.

BACKGROUND INFORMATION

Microevolution is the term used to describe changes that occur within a population of a single species. It includes the process of natural selection, changes in allele frequencies, and changes in populations that result over time. Industrial melanism and development of antibiotic-resistant bacteria are examples of microevolution.

Macroevolution refers to large-scale and long-term evolutionary patterns among many species. The evolution of new species from a common ancestor, as seen in Hawaiian honeycreepers and Darwin's finches, or the origin, adaptive radiation, and extinction of the dinosaurs are examples of macroevolution. Evolutionary biologists today are debating the extent to which microevolutionary mechanisms can explain macroevolutionary patterns (Martin, *Missing Links*).

ACTIVATE

Natural Selection in a Candy Dish—Demonstration

In this learning activity, students become unwitting subjects in a demonstration about natural selection. Students select candies from a bowl and have the opportunity to think about what brought about the "survival" of some candies. See Appendix 3.7: Natural Selection in a Candy Dish (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

ACQUIRE/APPLY

Natural Selection in Legocarnivora—Investigation (U2, S3, S4, S5)

This learning activity simulates natural selection with fictitious animals constructed of Lego® blocks. See Appendix 3.8A: Natural Selection in Legocarnivora (BLM) for the investigation. Also see Appendix 3.8B: Natural Selection in Legocarnivora (Answer Key).

Suggestion for Assessment

Specify in advance the criteria for assessment of the investigation. Lab skills and group work skills can be assessed using a checklist. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

Natural Selection

Specific Learning Outcome

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

I'm Looking over a White-Striped Clover: A Case for Natural Selection—Case Study/Culminating Task (U2, S1, S5, I1)

A case study can be used as a culminating task for the unit, bringing together a number of knowledge and skills and attitudes outcomes.

The case study "I'm Looking over a White-Striped Clover" by Susan Evarts, Alison Krufka, and Chester Wilson (available on the National Center for Case Study Teaching in Science website) explores the process of natural selection. Regardless of whether students work on the case study individually or in small groups, encourage them to use effective reading strategies to acquire new knowledge and information from the text. This includes activating their prior knowledge before reading the case study, taking some form of notes while reading, and having an opportunity to discuss and/or reflect on what they read in the case study.

Resource Links

- Evarts, Susan, Alison Krufka, and Chester Wilson. "I'm Looking over a White-Striped Clover: A Case of Natural Selection." 28 Nov. 2006. *Case Collection.* National Center for Case Study Teaching in Science. <http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=272&id=272>. Case Teaching Notes are available at <http://sciencecases.lib.buffalo.edu/cs/files/clover_notes.pdf>.

- National Center for Case Study Teaching in Science, University at Buffalo. Home Page. <http://sciencecases.lib.buffalo.edu/cs/>.

  This website provides access to a variety of case studies, which teachers can modify or adapt for classroom use, subject to the specified usage guidelines. Teaching notes and answer keys for the case studies are available free of charge. To access the answer keys, users are required to register for a password.

Suggestion for Assessment

Whatever the form of assessment used, students should be made aware of the criteria beforehand. Assessment criteria can be developed in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

Understanding Natural Selection (U1, N1, N3)

The use of examples will enhance students' understanding of how natural selection leads to changes in populations. There are many cases in which natural selection has been observed in action, including H. B. Kettlewell's study of camouflage adaptation in a population of light-coloured and dark-coloured pepper moths in England, and the development of antibiotic-resistant bacteria ("superbugs") such as *Staphylococcus aureus.*

Suggestion for Assessment

The use of Note Frames assists teachers in monitoring students' understanding (formative assessment). The information gained from Note Frames can be used to adjust teaching to address difficulties. Students can also compare their Note Frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-05: Explain how natural selection leads to changes in populations. (GLOs: D1, E3)

Examples: industrial melanism, antibiotic-resistant bacteria, pesticide-resistant insects . . .

I'm Feeling Better, So Why Do I Need to Finish This Prescription?—Microtheme (U2, S1, D4, I1, I2, I4)

Microthemes are short writing assignments designed to help students learn the material by looking at it in a different way (Martin). They require more than simply reading the text or articles and memorizing notes. A specific problem is addressed in each microtheme, allowing the writer to illustrate his or her understanding. Refer to Appendix 2.8A: Microthemes (Teacher Background) for more information on microthemes.

Provide students with the following scenario:

> *Your friend was recently diagnosed with strep throat, an infection that causes a sore throat and fever. Her doctor said the infection is easily treated and cured and gave her a prescription for an antibiotic. When you accompanied your friend to the pharmacist to get the prescription filled, the pharmacist told her to finish all the antibiotic pills, and not discontinue taking it, even if she started to feel better.*
>
> *After taking the antibiotic pills for three days, your friend started to feel better. She is thinking about not finishing the treatment. Explain to your friend why it is important that she finish the entire antibiotic treatment. Refer to variation and natural selection in your explanation.*

Suggestion for Assessment

Discuss assessment criteria for the microtheme with the class. Refer to Appendix 2.8B: Microthemes—First Draft Checklist (BLM) and Appendix 2.8C: Microthemes—Final Draft Assessment (BLM).

In their responses, students should discuss the development of antibiotic-resistant bacteria as an example of natural selection in action. Variation in antibiotic resistance occurs naturally within a bacterial population. Some bacteria have a low resistance and are killed rapidly when the antibiotic is present. However, some bacteria do survive and reproduce, as they are better adapted to their environment (i.e., more fit). To kill the more resistant bacteria, the entire course of antibiotic treatment must be completed.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-D4: Recommend an alternative or identify a position, and provide justification for it. (GLO: C4)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

B12-0-N3: Recognize both the power and limitations of science in answering questions about the world and explaining natural phenomena. (GLO: A1)

If treatment stops before all the bacteria are killed, the resistant bacteria will survive and reproduce. With less competition from other bacteria, the resistant bacteria population quickly increases. The person will likely become sick with the same illness again. The antibiotic that had once controlled the bacteria is no longer effective. The person may require longer treatment with the same antibiotic or may require a different antibiotic for treatment.

EFFECTS OF NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

SLO: B12-3-06

SUGGESTIONS FOR INSTRUCTION

ACTIVATE

Bell-Shaped Curve—Demonstration

Working in pairs, students measure their heights and round off the measurements to the nearest 0.05 metres (e.g., 1.60 m, 1.85 m). As a large group, determine the maximum and minimum heights of students in the class. Draw a continuum across the whiteboard, with the minimum and maximum heights at opposite ends. In between these heights, note the intermediate heights on the board. Ask students to stand in front of the board at their height. Should there be more than one student per height, ask the students to form a row in front of the height. When the students are organized, a bell-shaped curve will likely result. This reflects the height variation of students in the classroom.

ACQUIRE/APPLY

The Effects of Selection on Variation (U1)

With the use of graphs and examples, illustrate the effects of stabilizing, directional, and disruptive selection on the variation in a population. Refer to Appendix 3:9: Effects of Selection on Variation (Teacher Background) for more information.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Suggestion for Assessment

During the last five minutes of the class, have students complete an Exit Slip, reflecting on questions such as the following:

- What do you know now that you didn’t know before class today?
- What did you already know?
- What questions do you still have?

Review students’ responses, looking for areas of confusion, and address the questions during the next class (formative assessment). For information on Exit Slips, see *SYSTH* (p. 13.9).

Three-Point Approach (U2)

Graphic organizers enhance students’ learning, as they assist students in clarifying their thinking. Have students complete a Three-Point Approach frame for the following terms: *stabilizing*, *directional*, and *disruptive selection*. For more information on the Three-Point Approach, refer to *SYSTH* (pp. 10.9–10.10, 10.22).

Suggestion for Assessment

Assess students’ Three-Point Approach frames for conceptual understanding, and, if necessary, adjust instruction to address students’ misconceptions.

EFFECTS OF NATURAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-06: Describe how disruptive, stabilizing, and directional natural selection act on variation. (GLOs: D1, E3)

Investigating Variation—Investigation (U2, P1, S3, S4, S5, I4)

In this learning activity, students examine observable differences in a trait. Students measure the length of dried beans (e.g., kidney, lima, pinto) and graph the class results. For details on this investigation, refer to Appendix 3.10A: Investigating Variation (BLM) and Appendix 3:10B: Investigating Variation (Answer Key).

Suggestions for Assessment

Specify in advance the criteria for assessment of the investigation. For information on the process of developing assessment criteria in collaboration with students, refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background). Lab skills and group work skills can be assessed using a checklist. Refer to Appendix 1.3: Student Lab Skills (Teacher Background), Appendix 1.4A: Lab Skills Checklist—General Skills (BLM), Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM), and Appendix 1.13: Collaborative Process—Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P1: Demonstrate confidence in ability to carry out investigations. (GLOs: C2, C5)

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S4: Evaluate the relevance, reliability, and adequacy of data and data-collection methods. (GLOs: C2, C4, C5, C8)

Include: discrepancies in data and sources of error

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

ARTIFICIAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

SLO: B12-3-07

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Students will be familiar with artificial selection with respect to various breeds of dogs and cats. Some may be familiar with varieties of fruits and vegetables or varieties of domestic farm animals (e.g., horses, cattle, chickens).

BACKGROUND INFORMATION

Both natural selection and artificial selection are mechanisms of change in the gene pool of a population. The key difference is that in artificial selection, humans ensure that individuals with the more desirable traits are allowed to reproduce. In natural selection, those individuals who are best suited to their environment survive and reproduce.

Artificial selection is a form of non-random mating, one of the causes of change to a gene pool. For centuries, breeders have used the natural variation within a population to breed selectively those plants or animals that best represent the properties they wish for in future generations, such as more productive milk cows, earlier ripening fruits, greater grain yields, and faster racehorses. Charles Darwin was able to use artificial selection as a model for change in the natural world (i.e., natural selection).

ACTIVATE

What Makes a Squash, a Squash?—Demonstration

Provide students with samples of different types of winter squash such as acorn, butternut, Hubbard, pumpkin, and spaghetti squash. All are members of the same species, *Curcurbita maxima*. Ask students to write an explanation of how they think humans were able to produce such a variety of squash.

Alternatively, the many varieties of *Brassica oleracea* (e.g., broccoli, broccoflower, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi, collard greens, Chinese broccoli, rapini) could be used in this demonstration. All these varieties are derived from wild mustard through artificial selection.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Guest Speaker (U2, P2, I1)

Invite a local plant or animal breeder to the class. Have students prepare questions for the speaker in advance of the visit.

Questions could include the following:

- What type of plant/animal do you breed?
- What are the traits for which your plant/animal is bred?
- What selective breeding practices do you use for your animals? How do you propagate your plants?

This is also a good opportunity for students to explore related careers.

Suggestion for Assessment

Students summarize the highlights of the guest speaker's presentation in their notebooks. Summaries can be shared with classmates and peer assessed for content. For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

ARTIFICIAL SELECTION

SPECIFIC LEARNING OUTCOME

B12-3-07: Distinguish between natural selection and artificial selection. (GLOs: D1, E1, E3)

Artificial Selection—Field Trip (U2, P2, I1)

Visit a plant research station, a local horticulturalist, or an animal breeder for a demonstration of traits selected for in a plant or an animal and the selective breeding practices used. This is a good opportunity for students to explore related careers.

Suggestion for Assessment

Have students complete an I Used to Think, But Now I Know reflection after the field trip. Ask students to recall their ideas at the start of the topic discussion, and explain how their ideas changed or became more detailed compared to what they knew at the beginning of instruction (Keeley). Students can discuss their reflections with a partner.

Breed of Organism—Research and Presentation (U2, I1, I2, 14)

Students individually select and research a breed/varietal/cultivar of organism (e.g., Siamese cat, Hereford cattle, hybrid tea rose, cocker spaniel, hard red spring wheat). In their report findings, students should include the following:

- the name of the breed/varietal/cultivar
- the characteristics or traits selected for
- a picture of a representative organism

Suggestions for Assessment

Students prepare and present their research reports. Research findings can be presented in a variety of formats:

- multimedia presentation (e.g., PowerPoint, video, wiki)
- written report
- visual display (poster, bulletin board)

Develop assessment criteria for the report and presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit. Presentation components will vary, depending on the type of presentation (oral or written).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)
Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P2: Demonstrate a continuing, increasingly informed interest in biology and biology-related careers and issues. (GLO: B4)

B12-0-S1: Use appropriate scientific problem-solving or inquiry strategies when answering a question or solving a problem. (GLOs: C2, C3)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)
Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)
Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Where Did All the Four-Leaf Clovers Go?—Case Study (U2, S1, S5)

Have students answer questions in response to the case study presented in Appendix 3.11A: Where Did All the Four-Leaf Clovers Go?—Case Study (BLM). Also see Appendix 3.11B: Where Did All the Four-Leaf Clovers Go?—Case Study (Answer Key).

Suggestion for Assessment

Completed case studies can be handed in for teacher feedback. The feedback provided should be specific and descriptive, describing the performance rather than making a judgment or giving an opinion.

POPULATION GENETICS

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

SLO: B12-3-08

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Prior to discussing the Hardy-Weinberg principle equation, introduce students to the conditions required to maintain genetic equilibrium. Emphasize that as it is virtually impossible to meet these conditions, allelic frequencies do change in populations and, therefore, evolution does occur.

The main application of the Hardy-Weinberg principle in population genetics is in calculating allele and genotype frequencies in a population. It is the means by which changes in gene frequency and their rate of change are determined. Students should have the opportunity to perform population genetics calculations.

BACKGROUND INFORMATION

The *Hardy-Weinberg principle* is a mathematical model that deals with the frequencies of alleles in a gene pool. If the allelic frequency does not change in a population over successive generations, then evolution does not occur and the population is at equilibrium. The following conditions must be met to maintain this equilibrium:

- No mutation occurs so that the alleles do not change.
- Immigration and emigration do not occur as they would alter the gene pool.
- The population must be large so that changes do not happen by chance alone.
- All reproduction must be totally random so that one form of the allele is not selected for over another.
- All forms of the allele must reproduce equally well so that there is no natural selection.

As it is virtually impossible to meet these conditions, allelic frequencies do change in populations and, therefore, evolution does occur. The Hardy-Weinberg principle is also useful in explaining why genotypes within a population tend to remain the same, as well as for determining the frequency of a recessive allele.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

ACTIVATE

Earlobe Allele Frequencies—Demonstration

Students often wonder why recessive alleles do not disappear from a population. This demonstration can be used to illustrate the frequency of a recessive allele. Free earlobes are caused by a dominant gene (*E*), while attached earlobes are due to the homozygous recessive gene (*ee*).

1. Survey the class to determine the number of students with free earlobes and the number with attached earlobes.

   Sample data: 15 students with free and 5 with attached earlobes

2. Determine the frequency of the recessive allele using the frequency of individuals homozygous for the recessive allele (q^2).

   Sample data: 5/20 students (25% or 0.25) are *ee* (i.e., q^2). The frequency of the recessive allele is the square root of 0.25, or 0.50 (i.e., q). Remind students that all calculations are carried out using proportions, not percentages.

3. Determine the frequency of the dominant allele using $p + q = 1$.

   Sample data: The frequency of the dominant allele is, therefore, 1 – 0.50 or 0.50 (i.e., $1 - q = p$).

4. Determine the frequency of individuals homozygous for the dominant allele (p^2).

   Sample data: $(0.50)^2 = 0.25$

5. Determine the frequency of heterozygous individuals ($2pq$).

   Sample data: $2(0.50)(0.50) = 0.50$

6. Check calculations using the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$).

   Sample data: $0.25 + 2(0.50)(0.50) + 0.25 = 1$

POPULATION GENETICS

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

Discuss how this example illustrates how frequently a recessive gene may occur in a population, even though the number of homozygous recessive individuals is quite low.

ACQUIRE/APPLY

Introducing the Hardy-Weinberg Principle Equation (U1)

Introduce students to calculations of allele and genotype frequencies using the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$). This equation can be applied to populations with a simple genetic situation, with dominant and recessive alleles controlling a single trait.

In a population, the frequency alleles in a stable population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele
q = frequency of the recessive allele

Use the example below to illustrate the Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$), where

p^2 = frequency of individuals homozygous for the dominant allele
q^2 = frequency of individuals homozygous for the recessive allele
$2pq$ = frequency of individuals with the heterozygous genotype

The distribution of the sickle-cell anemia allele can be used as an example for calculations. In some areas of Africa, the recessive sickle-cell allele has a frequency of 0.3. The frequency of the normal hemoglobin allele is calculated as 1 – 0.3 = 0.7.

$2(0.70)(0.3) = 0.42 = Ss$ (42% of the population)
$0.3^2 = 0.09 = ss$ (9% of the population affected by sickle-cell anemia)
$0.49 + 0.42 + 0.09 = 1$

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)
Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)
Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

Based on these calculations, one can determine that although a relatively small percentage of individuals (9%) in the population are affected by sickle-cell anemia, the recessive allele is widely distributed in the population. In fact, 51% of the population carries at least one copy of the sickle-cell allele. This example can be used to illustrate why recessive alleles are not removed from a population, even though the number of individuals with the homozygous recessive condition may be quite low.

Population Genetics Calculations—Each One Teach One (U2, G2)

Provide pairs of students with a variety of problems involving Hardy-Weinberg principle equation calculations. Students work collaboratively to solve the problems and explain to their partners how they were able to determine answers to the problems (their metacognitive processes). See Appendix 3.12A: Population Genetics Calculations (BLM) and Appendix 3.12B: Population Genetics Calculations (Answer Key). The sample problems and answers provide examples of typical problems and solutions.

Suggestion for Assessment

Completed calculations can be handed in for teacher feedback. Provide feedback that is specific and descriptive, describing the performance rather than making a judgment or giving an opinion. This will help students repeat success and know what they need to improve. General comments (e.g., "Try harder next time" or "Good work") are less effective than specific and descriptive comments (e.g., "You have correctly determined the frequency of the dominant and recessive alleles. Check your work: does $0.2^2 = 0.4$?").

POPULATION GENETICS

SPECIFIC LEARNING OUTCOME

B12-3-08: Outline how scientists determine whether a gene pool has changed, according to the criteria for genetic equilibrium. (GLOs: D1, E3)

Include: large population, random mating, no gene flow, no mutation, and no natural selection

Using the Hardy-Weinberg Principle Equation—Investigation (U2, S3, S5)

Students calculate the gene and allele frequencies of a human trait. Refer to Appendix 3.13A: Using the Hardy-Weinberg Principle Equation—Investigation (BLM) and Appendix 3.13B: Using the Hardy-Weinberg Principle Equation—Investigation (Answer Key).

Suggestion for Assessment

Assess the responses to determine students' levels of conceptual understanding and to guide further teaching and/or learning activity selection (if needed).

The Hardy-Weinberg Principle—Demonstrating Understanding (U1)

Pose the following to students:

- Some people think that the dominant allele of a gene should constantly increase in frequency in a population, and quickly force out the recessive allele. Use the Hardy-Weinberg principle and/or equation to explain why this idea is incorrect. What false assumption could cause people to have this incorrect idea?

Suggestion for Assessment

This task provides a quick formative assessment of what students learned in a particular lesson. Students' responses should include the following:

- People may assume that because few individuals show the recessive phenotype, the recessive allele is rare.
- The Hardy-Weinberg principle equation can show how widespread a recessive allele is in a population, even though few individuals show the recessive phenotype.
- Large populations are relatively genetically stable and large shifts in allele frequencies do not occur from one generation to the next.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-S3: Record, organize, and display data and observations using an appropriate format. (GLOs: C2, C5)

B12-0-S5: Analyze data and/or observations in order to explain the results of an investigation, and identify implications of these findings. (GLOs: C2, C4, C5, C8)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

NOTES

MECHANISMS FOR GENETIC VARIATION

SPECIFIC LEARNING OUTCOME

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

SLO: B12-3-09

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

In learning outcome B12-3-08, students are introduced to the conditions required to maintain genetic equilibrium. Students should understand that, as it is virtually impossible to meet these conditions, allelic frequencies do change in populations. Use this as a springboard for a discussion into how genetic variation in a gene pool can be altered.

BACKGROUND INFORMATION

- Natural selection affects variations in a population, as the better adapted (more fit) individuals survive and reproduce, passing on their genes to successive generations.
- Immigration and emigration of individuals from a population will affect allele frequencies and, therefore, gene flow.
- The change in the gene pool of a small population due to random chance is *genetic drift*. The bottleneck effect is a form of genetic drift that results from the near extinction of a population. The *founder* effect is a form of genetic drift that results from a small number of individuals colonizing a new area. In both cases, allele frequencies can change dramatically.
- In animals, non-random mating is often the case, as the choice of mates is often an important part of behaviour (e.g., courtship rituals). Many plants self-pollinate, which is a form of inbreeding or non-random mating.
- Mutations occur constantly. They provide the source of new alleles, or variations upon which natural selection can take place.

ACTIVATE

Thinking Like a Scientist

Ask students to recall the conditions required to maintain genetic equilibrium (see learning outcome B12-3-08 for details). Reminding students that it is virtually impossible to meet these conditions, ask students to think like scientists and work in groups to propose situations/events that may alter a gene pool. For example, the condition of no gene flow could be affected by immigration and emigration.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

ACQUIRE/APPLY

How Can Variation in a Gene Pool Be Altered? (U1)

Use the Hardy-Weinberg principle equation, in conjunction with simulations, animations, and examples, to demonstrate how the allele frequencies in a founding population can evolve differently from those of the parent population.

There are many known instances of the founder effect in human populations, including

- tyrosinemia in the Québécois of the Saguenay–Lac-Saint-Jean region (see Appendix 1.10A: Using Pedigree Analysis to Solve a Genetic Mystery [BLM])
- limb-girdle muscular dystrophy in Manitoba Hutterites
- retinitis pigmentosa on the island of Tristan da Cunha
- Ellis-van Creveld syndrome in the Pennsylvania Amish community

Resource Links

- Jones, Thomas C. "PopGen Fishbowl 1.0." Virtual Ecology. *Population Genetics*. <http://faculty.etsu.edu/jonestc/virtualecology.htm>.

  This population genetics simulation contains the tools to conduct virtual experiments violating all the assumptions of the Hardy-Weinberg principle.

- Oklahoma State University. "Speciation Tutorial." 18 Nov. 2010. *Biology 1114*. <http://zoology.okstate.edu/zoo_lrc/biol1114/tutorials/Flash/life4e_15-6-OSU.swf>.

  This animation illustrates the effects of changing the Hardy-Weinberg principle conditions on a population.

- PBS Online. "Sex and the Single Guppy." *Evolution*. <www.pbs.org/wgbh/evolution/sex/guppy/low_bandwidth.html>.

  This website examines the interplay between natural and sexual selection in a population of wild guppies.

- Virtual Ecology. *Virtual Ecology Project*. <http://faculty.etsu.edu/jonestc/virtualecology.htm>.

MECHANISMS FOR GENETIC VARIATION

SPECIFIC LEARNING OUTCOME

B12-3-09: Discuss how genetic variation in a gene pool can be altered. (GLOs: D1, E1, E3)

Examples: natural selection, gene flow, genetic drift, non-random mating, mutation . . .

Suggestion for Assessment

At the end of the lesson, ask students to describe the most significant point made during the lesson that contributed to their learning (Keeley). The POMS (point of most significance) can be made orally or in writing. Analyze students' responses to determine whether instructional adjustments need to be made. Let students know you will be using the information to plan the next lesson to benefit them. This will help them realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

Population Bottlenecks and Endangered Species—Case Study (U2, P3)

See Appendix 3.14A: Population Bottlenecks and Endangered Species—Case Study (BLM) and Appendix 3.14B: Population Bottlenecks and Endangered Species—Case Study (Answer Key) for a learning activity about the endangered whooping crane.

Suggestion for Assessment

Assess students' responses for conceptual understanding, and provide descriptive feedback as to how they could be improved.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-P3: Recognize the importance of maintaining biodiversity and the role that individuals can play in this endeavour. (GLO: B5)

NOTES

SPECIATION

SPECIFIC LEARNING OUTCOME

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

SLO: B12-3-10

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

You may wish to discuss with students the definition of species. (See learning outcomes B12-4-01 and B12-4-02 for more information.) The evolutionary biologist Ernst Mayr defined a *species* as a reproductive community of populations (reproductively isolated from others) that occupies a specific niche in nature.

BACKGROUND INFORMATION

When a part of a population becomes geographically isolated from the parent population, *allopatric speciation* can occur. Geographic isolation can occur due to the formation of physical barriers (e.g., mountains, canyons, rising sea levels, glaciers). The physical barrier prevents gene flow between the two populations. If the different populations are subjected to different natural selection pressures, allele frequencies for genes will change. The two populations may accumulate substantial genetic differences so that they become reproductively isolated and are unable to interbreed; therefore, two distinct species result.

When the gene flow between members of a population is restricted due to ecological isolation (niche differentiation), *sympatric speciation* can occur. Some members of a population may be better adapted to a slightly different habitat in an ecosystem, and begin to specialize in that habitat. Different selective pressures in the two habitats lead to genetic changes in the organisms. The two populations become reproductively isolated, and two distinct species result, even though there are no physical barriers separating the population.

Alterations in behaviour can lead to reproductive isolation. Should a group of nocturnal mammals become active during the day, they may no longer interbreed with their counterparts who are active at night. Chromosome mutation can also result in reproductive isolation. A malfunction in meiosis can lead to polyploidy (multiple copies of chromosomes) in a plant. Because plants can reproduce asexually and self-pollinate, the new polyploid can reproduce, even though it is reproductively isolated from its parent(s).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

ACTIVATE

Darwin's Finches

Provide students with pictures or diagrams of some of the 14 Galapagos Islands finches (with their beaks showing), as well as information about the diet of each of the species illustrated. Ask students to hypothesize how these differences evolved from one ancestral species.

ACQUIRE/APPLY

Stages of Allopatric Speciation—Jigsaw (U2, G1, G3)

The Jigsaw (Aronson et al.) is a cooperative learning strategy that enables students to become experts on part of a topic, which they share with others.

Divide the class into four groups, and assign to each home group a particular stage in the process of allopatric speciation:

- stage 1: two populations with normal gene flow
- stage 2: gene flow is prevented by a geographical barrier
- stage 3: genetic differences accumulate
- stage 4: two populations are reproductively isolated

Each group investigates the characteristics and events of the assigned stage and prepares a summary. One student from each group then moves to another group, so that each new group has one expert from each of the previous groups. Each expert shares his or her summary with the new group members. In this way, all members of the class receive the summaries of all the groups. If paper copies of the summaries are provided, the experts should be prepared to discuss the important points of their respective summaries. For more information about the Jigsaw strategy, see *SYSTH* (p. 3.20).

SPECIATION

SPECIFIC LEARNING OUTCOME

B12-3-10: Describe how populations can become reproductively isolated. (GLOs: D1, E2)

Examples: geographic isolation, niche differentiation, altered behaviour, altered physiology . . .

Suggestion for Assessment

Group work skills can be assessed with a checklist. Refer to Appendix 1.13: Collaborative Process—Assessment (BLM).

The Process of Speciation (U1)

Use actual or hypothetical examples to complement a discussion of the process of speciation. Remind students that new species result when members of a population become reproductively isolated from one another and no longer interbreed to produce fertile offspring in their natural environment.

Use note-taking strategies such as the following to provide students with processing time to enhance their conceptual understanding:

- **10 + 2 Note Taking:** Present information for 10 minutes, and then have each student summarize or discuss the material with a partner for two minutes.
- **Three-Minute Pause:** Lecture for a period of time, and then pause for three minutes to allow students to process information with a partner or a small group.

Resource Link

- PBS Online. "An Origin of Species." *Evolution*. <www.pbs.org/wgbh/evolution/darwin/origin/>.
  This website allows students to see how a new species can evolve by observing natural selection and adaptive radiation in action.

Suggestion for Assessment

Pose the following question to students at the end of the lesson:

- How has your understanding of the term *speciation* changed in this lesson?

Give students five minutes to respond in their notebooks.

This quick formative assessment provides information about what students learned in a particular lesson. Students' responses should indicate a clearer understanding of the biological definition of *speciation*.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-G1: Collaborate with others to achieve group goals and responsibilities. (GLOs: C2, C4, C7)

B12-0-G3: Evaluate individual and group processes used. (GLOs: C2, C4, C7)

Speciation—Chain Concept Map (U2)

Provide students with the following list of key terms related to speciation:

- adapt
- gene pool
- interbreed
- population
- reproductive isolation
- selection
- speciation
- species

Students use these key terms, and any others they might wish to add, to create a Chain Concept Map that illustrates the process of speciation. Students may base their concept maps on a type of speciation (e.g., allopatric, sympatric) or on a real or hypothetical example (e.g., Darwin's finches, geographic isolation due to the formation of an inland sea). Inspiration software can be used to create concept maps. For more information on concept maps, refer to *SYSTH* (pp. 11.11–11.18).

Suggestion for Assessment

Assess students' Chain Concept Maps for logic in the layout and linkages, as well as for accurate use of terminology, and adjust teaching to address any difficulties identified.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

SLO: B12-3-11

SUGGESTIONS FOR INSTRUCTION

BACKGROUND INFORMATION

Divergent evolution (also known as *adaptive radiation*) is the process in which an ancestral species gives rise to a number of new species that are adapted to different environmental conditions. This often occurs when a species colonizes a new environment in which there are unoccupied ecological niches. For example, the adaptive radiation of Hawaiian honeycreepers and Darwin's finches occurred on islands. In other cases, adaptive radiation occurred after the extinction of many other species. The rapid increase in the number of species of mammals took place after the mass extinction of the dinosaurs.

Convergent evolution is the process in which different organisms that live in similar habitats become more alike in appearance and behaviour. As they encounter similar environmental pressures, the organisms develop analogous structures. For example, dolphins and sharks live in the water and both use their tails for propulsion. However, their tails are analogous structures with different origins. Sharks move their tails side to side, while dolphins move their tails up and down. Similarly, bat, butterfly, and bird wings are analogous structures.

ACTIVATE

Vocabulary: Recall and Predict

Pose the following questions to students and have them use their prior vocabulary knowledge to predict the meaning of new terminology:

- Can you recall the term *homologous*? Hint: Think of homologous chromosomes. What does *homologous* mean? (similar or related)
- Based on your knowledge of homologous chromosomes, can you predict to what *homologous structures* refer? (similar or related structures in organisms—e.g., human arm, bird wing, dog foreleg)
- What does the term *analogous* mean? Hint: Think of the word *analogy*. (partial similarity, corresponding in some manner)
- Can you predict to what structures *analogous structures* refer? (structures correspond in function, but are not related in origin—e.g., butterfly wing, bird wing)

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

ACQUIRE/APPLY

Homologous and Analogous Structures—Demonstration (U1)

Obtain samples of bird wings (e.g., turkey, chicken, duck) and samples of insect wings (e.g., butterfly, moth, dragonfly).

- Use the bird wings to illustrate homologous structures. Describe the structure and function of a bird's wing. Have students identify the homologous structures in the various bird wings.
- Present the insect wings to students. Describe the structure and function of an insect's wing. Ask students to identify the homologous structures in the various insect wings.

Note that homologous structures are evidence that organisms evolved from a common ancestor. The differences among homologous structures are the result of adaptations to different environments.

Suggestion for Assessment

Ask students to compare the bird wings with the insect wings and have them record their ideas. Students should note that the bird and insect wings have similar functions, but their structures are quite different. Bird wings and insect wings are analogous structures. They do not have a common evolutionary ancestor, but have similar functions. Analogous structures are the result of adaptations to a similar environment. Review students' responses with the class to check for understanding.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

Comparing Convergent and Divergent Evolution (U1)

With the use of examples, compare divergent and convergent evolution by focusing on the key differences between the two processes. Differentiate between homologous and analogous structures using pictures, video clips, and/or diagrams. Evidence for evolution is provided for by homologous structures, as they indicate descent from a common ancestor. Analogous structures also give evidence for evolution, as they show how dissimilar organisms can independently adapt to similar environments.

Resource Links

- British Broadcasting Corporation. *BBC Motion Gallery*. <www.bbcmotiongallery.com/>.

  An extensive collection of video footage is available on this website.

- Thanukos, Anna. "Similarities and Differences: Understanding Homology and Analogy." *Understanding Evolution*. University of California Museum of Paleontology. <http://evolution.berkeley.edu/evolibrary/article/similarity_hs_01>.

  This interactive module explores homologies and analogies and why they are important in evolution.

Suggestion for Assessment

Show video clips of a fish swimming and a whale swimming, focusing on the motion of the tails. Ask students whether the tails are homologous or analogous structures and have them explain their reasoning. Adjust instruction to address any difficulties identified.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

Homologous and Analogous Structures—Research and Presentation (U2, I1, I2, I3, I4)

Have students research examples of homologous and analogous structures (e.g., Canada goose wing, little brown bat wing, mosquito wing) and prepare reports containing the following information:

- examples of two organisms that share a homologous structure
- a description of the homologous structure
- an explanation of how the difference in structure is an adaptation to a different environment
- an example of an organism that has a structure analogous to one of the homologous structures
- a description of the analogous structure
- an explanation of how the similarity in function is an adaptation to a similar environment

Resource Links

- Manitoba Education. *Information and Communication Technology (ICT): Kindergarten to Grade 12*. <www.edu.gov.mb.ca/k12/tech/index.html>.

  Visit this website for ideas about integrating information and communication technologies across the curriculum.

- ———. "Professional Learning for Teachers." *Literacy with ICT across the Curriculum: A Developmental Continuum*. <www.edu.gov.mb.ca/k12/tech/lict/let_me_try/le_teachers.html>.

  Information on topics such as plagiarism, evaluating web content, copyright, and making a bibliography can be accessed at this website.

CONVERGENT AND DIVERGENT EVOLUTION

SPECIFIC LEARNING OUTCOME

B12-3-11: With the use of examples, differentiate between convergent evolution and divergent evolution (adaptive radiation). (GLOs: D1, E1)

Suggestions for Assessment

Students present their research on homologous and analogous structures. Research findings can be presented as

- written reports
- visual displays (e.g., poster, brochure, bulletin board exhibit, comic strip)
- oral presentations
- multimedia presentations (e.g., podcast, wiki, PowerPoint, video)

Presentation components may vary, depending on the type of presentation. Refer to Appendix 5.8: Checklist for Creating Visuals (BLM) for use with visuals (e.g., posters, collages, graphic organizers) and Appendix 5.9: Oral Presentation—Observation Checklist (BLM).

Develop assessment criteria for the presentation in collaboration with students. Refer to Appendix 5.7: Co-constructing Assessment Criteria with Students (Teacher Background) for more information on the collaborative process. The criteria should include both content and presentation components. The content criteria should include use of key terms and understandings from the unit.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I1: Synthesize information obtained from a variety of sources. (GLOs: C2, C4, C6)

Include: print and electronic sources, resource people, and different types of writing

B12-0-I2: Evaluate information to determine its usefulness for specific purposes. (GLOs: C2, C4, C5, C8)

Examples: scientific accuracy, reliability, currency, relevance, balance of perspectives, bias . . .

B12-0-I3: Quote from or refer to sources as required, and reference sources according to accepted practice. (GLOs: C2, C6)

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

NOTES

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

SLO: B12-3-12

SUGGESTIONS FOR INSTRUCTION

TEACHER NOTE

Discuss with students that evolutionary theory continues to be refined and expanded as our knowledge of biology grows. The debate over gradualism versus punctuated equilibrium is just one example of the "evolution" of evolutionary theory.

BACKGROUND INFORMATION

The new or modern synthesis of evolutionary theory (sometimes called neo-Darwinism) contains findings from genetics, population biology, paleontology, and, most recently, from evolutionary developmental (evo-devo) biology. Key contributors include the following:

- **Theodosius Dobzhansky** (1900–1975) was one of the biologists initiating modern evolutionary theory that unites the fields of genetics and evolution. He is notable for defining *evolution* as a change in the frequency of an allele in a gene pool, and is famous for his quotation, "Nothing in biology makes sense except in light of evolution" (1973).
- **Ernst Mayr** (1904–2005) was one of the biologists initiating modern evolutionary theory that unites the fields of genetics and evolution. His work included the development of the concept of biological species and proposed the mechanism of peripatric speciation.
- **Niles Eldredge** (1943–present) and **Stephen Jay Gould** (1941–2002) proposed the theory of punctuated equilibrium, which hypothesizes that changes in species can occur relatively quickly, with long periods of little change (equilibrium) in between.

Gradualism describes the pattern of slow and gradual evolutionary change over long periods of time. Populations slowly diverge from one another due to differing selective pressures. The changes result in transitional forms that are seen in the fossil record. Examples in the fossil record include the evolution of the trilobites.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Punctuated equilibrium describes the pattern of long stable periods in which species stayed much the same. These periods were interrupted (punctuated) by short periods in which the quick pace of evolution rapidly resulted in the formation of new species. The stimulus for evolution is a sudden significant change in the environment. The fossil record shows that rapid bursts of evolution have often followed mass extinctions (e.g., the Cretaceous extinction of the dinosaurs was followed by the rapid increase of mammalian species).

ACTIVATE

How Fast Does Evolution Occur?—Brainstorming

Introduce the topic of the pace of evolutionary change by posing the following questions to students:

- Have you ever wondered how fast evolution occurs?
- Does it occur at the same rate all the time?

Provide students with time to think about these questions individually, and ask them to record their thoughts in their notebooks.

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

ACQUIRE/APPLY

How Fast Does Evolution Occur?—Class Discussion (U2, G2)

Engage the class in a discussion of the pace/rate of evolutionary change, pointing out that the fossil record shows that some groups of organisms seem to have remained unchanged for millions of years. Ask students to come up with suggestions as to why the rate of evolution in organisms such as the cockroach, shark, and horsetail (*Equisitum*, a type of plant) is so slow. Possible answers include the following:

- stabilizing selection tends to keep allele frequencies relatively constant, thereby limiting evolution
- environmental conditions remained fairly constant
- few chromosomal mutations have occurred

Then, indicate that the fossil record shows that some groups of organisms seem to have undergone rapid speciation events. Ask students to come up with suggestions as to why some species evolved so rapidly. Examples include the adaptive radiation in the Galapagos Islands finches, the Cambrian explosion of animal phyla, and the rise of the mammals in the Tertiary period. Possible answers include the following:

- genetic drift in a small isolated population
- mass extinction of many life forms (e.g., dinosaurs)
- rapidly changing environmental conditions (e.g., meteor strike, glaciation period)
- exploitations of new niches (due to extinction or colonization)

Suggestion for Assessment

Using information gathered from the class discussion, students complete a Compare and Contrast frame for gradualism and punctuated equilibrium (refer to *SYSTH*, pp. 10.15–10.18). Students can compare their completed frames and provide each other with feedback (peer assessment). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

Punctuated Equilibrium versus Gradualism (U1)

With the use of illustrations, differentiate between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. Note that these are extreme models. The majority of evolutionary biologists believe that some aspects of both models occur during the evolutionary history of a species. At some points there is gradual change, due to stabilizing selection and unchanging environmental conditions. At other points, genetic drift, directional selection, sudden environmental changes, or co-evolution can lead to rapid changes.

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don't get it), and thumbs sideways (I'm not sure I get it)—to check students' understanding. This quick formative assessment can be used to adjust the pace of instruction.

The Pace of Evolutionary Change—Demonstrating Understanding (U2, I4, N1)

Pose the following questions to students at the end of a lesson:

- How do proponents of punctuated equilibrium explain the scarcity of transitional forms (missing links) in the fossil record?
- How does their explanation differ from that offered by proponents of gradualism?

Give students five minutes to respond in their notebooks.

PACE OF EVOLUTIONARY CHANGE

SPECIFIC LEARNING OUTCOME

B12-3-12: Distinguish between the two models for the pace of evolutionary change: punctuated equilibrium and gradualism. (GLOs: D1, E3)

Suggestion for Assessment

Use this learning activity as a quick formative assessment of what students learned in a particular lesson. Students' responses should include the following:

- Proponents of punctuated equilibrium argue that transitional forms between species are missing because evolution occurs so rapidly in a very short period of time.
- Gradualists believe that transitional forms of organisms or missing links between species are missing from the fossil record because they are rare.

SKILLS AND ATTITUDES OUTCOMES

B12-0-U1: Use appropriate strategies and skills to develop an understanding of biological concepts. (GLO: D1)

Examples: use concept maps, sort-and-predict frames, concept frames . . .

B12-0-U2: Demonstrate an in-depth understanding of biological concepts. (GLO: D1)

Examples: use accurate scientific vocabulary, explain concept to someone else, make generalizations, compare/contrast, identify patterns, apply knowledge to new situations/contexts, draw inferences, create analogies, develop creative presentations . . .

B12-0-I4: Communicate information in a variety of forms appropriate to the audience, purpose, and context. (GLOs: C5, C6)

B12-0-G2: Elicit, clarify, and respond to questions, ideas, and diverse points of view in discussions. (GLOs: C2, C4, C7)

B12-0-N1: Describe the role of evidence in developing scientific understanding and explain how this understanding changes when new evidence is introduced. (GLO: A2)

NOTES

Notes

Unit 3:
Evolutionary Theory and Biodiversity

Appendices

Appendix 3.1: The Nature of Science—Evolution (Teacher Background)

Non-scientists may confuse two aspects of the term *evolution*. Some may believe that evolution is only a theory, and therefore is not as believable as a law. It is important to understand that theories are explanations of observed phenomena and supported by a large body of evidence and experimentation. Theories are never "proven" into laws; they continue to be refined as more evidence supporting them is accumulated, or rejected when a better explanation of phenomena (another theory) is proposed. Laws are generalizations or patterns in nature (e.g., Boyle's law, Newton's laws of gravity, the laws of thermodynamics), often expressed as mathematical relationships.

Some difficulties associated with evolution arise when the distinction is made between the reality that evolution has occurred (the fact) and the explanation for how evolution occurs (the theory). Evolution is, indeed, a fact. There is a massive body of evidence in the fossil record, in embryological, morphological, and biochemical (DNA) studies, and so on, that demonstrates modern organisms evolved from older ancestral organisms, and modern species are continuing to change. What is less certain is the exact mechanism of evolution. Several theories have been suggested to explain this. Charles Darwin proposed a theory of natural selection to explain the mechanism of evolution. Biologists continue to debate the mechanisms of evolution today.

One of the key elements to the nature of science that students must understand is that there are limits to the questions that science can investigate. Science and its methods cannot address moral, ethical, aesthetic, social, and metaphysical questions, as they rely on evidence gained from nature, either directly or through inference. While scientists may have personal opinions on issues related to such questions, science inquiry is unable to provide answers to those questions.

Appendix 3.2A: Evolution Survey (BLM)*

Read the following statements and indicate whether each statement is true or false, in terms of how you think biologists use and understand the term *evolution* today. You do NOT necessarily have to AGREE with the statement for it to be true, as you think biologists see it. The purpose of this survey is to determine the level of understanding on this topic in this class, so that misconceptions can be discussed. In every case below, *evolution* means *biological evolution*.

Statements	Your Response (True or False)
1. Evolution was first proposed and explained by Charles Darwin.	
2. Evolution theory has been tested many times, and has always been supported by the evidence.	
3. Evolution is something that happens to individual organisms.	
4. Evolution is a process that involved the origin of life.	
5. Evolution is a scientific fact.	
6. Evolution is the same as natural selection.	
7. Evolution is only a theory.	
8. Evolution is something that happened only in the past; it is not happening now.	
9. The formation of complex structures, like the eye, can be readily explained by evolution.	
10. Science can properly infer what has happened in the past, based on evidence.	

* Source: University of Indiana. “Evolution Survey.” *Evolution and the Nature of Science Institutes*. <www.indiana.edu/~ensiweb/lessons/ev.surv.html> (5 Apr. 2011). Adapted with permission.

Appendix 3.2B:
Evolution Survey (Teacher Background)*

This survey can be used to uncover students' misconceptions regarding evolution. It is important to note that students are to indicate whether the statements are true or false according to how they think biologists understand evolution, not whether students agree or disagree with the statements.

Statements	**Your Response (True or False)**
1. Evolution was first proposed and explained by Charles Darwin.	FALSE: Others proposed that species changed over time.
2. Evolution theory has been tested many times, and has always been supported by the evidence.	TRUE: The body of evidence for evolution is extensive and expanding. All observations support it.
3. Evolution is something that happens to individual organisms.	FALSE: Evolution occurs in populations, not individuals.
4. Evolution is a process that involved the origin of life.	FALSE: Evolution deals only with the origin of species.
5. Evolution is a scientific fact.	TRUE: Evolution has been observed directly; there is no evidence against it.
6. Evolution is the same as natural selection.	FALSE: Natural selection is the mechanism by which evolution occurs.
7. Evolution is only a theory.	FALSE: Evolution is a scientifically demonstrated fact.
8. Evolution is something that happened only in the past; it is not happening now.	FALSE: Evolution is ongoing.
9. The formation of complex structures, like the eye, can be readily explained by evolution.	TRUE: Evolution is not a random or accidental process; there are selective aspects.
10. Science can properly infer what has happened in the past, based on evidence.	TRUE: There are no empirical observations of life, living or extinct, that evolution cannot explain.

* Source: University of Indiana. "Evolution Survey." *Evolution and the Nature of Science Institutes.* <www.indiana.edu/~ensiweb/lessons/ev.surv.html> (5 Apr. 2011). Adapted with permission.

Appendix 3.3: The Story of Charles Darwin (BLM)

The story of Charles Darwin is a fascinating one. While he is associated with the study of biology, he had actually graduated from Cambridge University with a degree in theology. He began his university training in medicine, but changed his studies when he found he could not stand the sight of blood.

Darwin's real interest lay in the area of natural history. He enjoyed hiking in the wilderness, observing nature, collecting plant and insect specimens, and classifying them. John Henslow, a botanist who accompanied Darwin on these hikes, recommended him to Robert FitzRoy, the captain of the HMS *Beagle*, as a companion on the voyage around the world. In 1831, the *Beagle* set sail with Charles Darwin onboard.

Over the next five years, Darwin observed and collected geological and biological specimens along the route. The letters and specimens he sent home during the voyage made him a well-known and respected naturalist. Upon his return to England, Darwin spent a number of years compiling his data and having his specimens classified. He became convinced that species could change over time. In 1838, after reading work by Thomas Malthus on the consequences of overpopulation, he had a flash of insight. He was able to propose a mechanism of evolution: natural selection.

Darwin drafted two manuscripts (1842 and 1844) in which he outlined his theory, but withheld them from publication, only showing the manuscripts to trusted friends. Why was Darwin reluctant to publish? Darwin knew his ideas would be controversial, and could be perceived as being contrary to the religious teachings of the time. But this was not the main reason for his reluctance to publish. Darwin recognized that there were two main aspects of his theory that were problematic at the time. He was unable to explain the origin of the variation within populations that natural selection acted upon, as well as the mechanism of the transmission of variation from one generation to the next.

In the mid-1850s, Alfred Russell Wallace conceived the same ideas as Darwin, based on his observations in Indonesia. He wrote a paper and sent it to Darwin to review. This finally spurred Darwin on to agree to the release of his theory. In 1858, Charles Lyell presented Darwin's 1844 essay and Wallace's paper to the public. Darwin's *On the Origin of Species by Means of Natural Selection* was published in 1859. The book is a well-constructed argument for natural selection, backed by considerable evidence.

Appendix 3.4: Postcards from the *Beagle*—Creative Writing Assignment (BLM)

Introduction

You are to assume the role of Charles Darwin during his five-year voyage on the HMS *Beagle*. While on your travels, you visit many places and see many fascinating things. Whenever you stop at a port, you send letters and notes home to family and friends. Select a region you have just visited, and send a 100-word postcard home to a friend describing your observations and thoughts about what you have seen in that area.

Here are some tips to get you started:

- Remember that Darwin formulated his theory of evolution by natural selection after his voyage was finished.
- Make your postcard clear and concise.
- Provide the name of the region or area you have written about (e.g., Tasmania, Galapagos Islands, Patagonia).
- Include at least one observation and one question or thought that arose in your mind from your observation.

All the postcards will then be fixed to a map of the world, tracing the voyage of the *Beagle*.

Appendix 3.5A: Natural Selection Simulation (BLM)

Introduction

On a distant planet in a galaxy far, far away, live creatures known as foofoos. While all foofoos eat beans, there are variations in their mouth parts. Some foofoos have a tweezer mouth, some have a needle mouth, and some have a clothespin mouth. One year, a new foofoo with a spoon mouth was discovered. These new foofoos are quite rare. In this lab activity, each of you will play the part of a foofoo on the planet and feed on beans.

Purpose

In this simulation, you will model natural selection by using different utensils to capture food.

Materials (possible substitutions)

- dissecting trays (paper plates)—one per group
- large bag of dried beans (e.g., kidney, lima, northern)
- 250 mL beakers (petri dishes, paper cups)—one per student
- clothespins (chopsticks)
- dissecting needles (dissecting pins, tacks)
- spoons
- tweezers

Procedure

1. Work in a group of three or four students. Obtain one dissecting tray for your group and add 100 dried beans to it. Obtain one 250 mL beaker for each group member.
2. Each group member will be provided with a utensil (utensils may vary). It is important to use the utensil to pick up beans as demonstrated by the teacher. Use caution when picking up beans, as some utensils may be sharp. Hold the utensil in one hand, and hold the beaker flat on the table in front of you with the other hand.
3. There will be four feeding times (trials). Each foofoo must eat 20 beans to survive to the next feeding time.
4. When the feeding time begins (as indicated by the teacher), use the utensil to pick up beans from the dissecting tray and place them in your beaker.
5. Count the number of beans "eaten" by each foofoo in your group and record the results in the Data Table that follows.
6. Repeat the procedure for the remaining feeding times and record the results for each trial in the Data Table.

Data Table

Student	Utensil	Trial 1	Trial 2	Trial 3	Trial 4

Analysis and Conclusions

1. Which type of foofoo was the best adapted to its environment? Explain your answer.
2. How does the type of mouth part affect the survival rate of foofoos?
3. What happens to the foofoos that cannot compete well with other foofoos? Explain.
4. How does the foofoo scenario model natural selection?

Appendix 3.5B: Natural Selection Simulation (Teacher Background)

Introduction (read to students)

On a distant planet in a galaxy far, far away, live creatures known as foofoos. While all foofoos eat beans, there are variations in their mouth parts. Some foofoos have a tweezer mouth (demonstrate how to use tweezers to pick up beans), some have a needle mouth (demonstrate), and some have a clothespin mouth (demonstrate). One year, a new foofoo with a spoon mouth (demonstrate) was discovered. These new foofoos are quite rare. In this lab activity, each of you will play the part of a foofoo on the planet and feed on beans.

Purpose

In this simulation, students model natural selection by using different utensils to capture food.

Materials (possible substitutions)

- dissecting trays (paper plates)—one per group
- large bag of dried beans (e.g., kidney, lima, northern)
- 250 mL beakers (petri dishes, paper cups)—one per student
- clothespins (chopsticks)
- dissecting needles (dissecting pins, tacks)
- spoons
- tweezers

Procedure

1. Remind students that exactly 100 beans must be added to the tray.
2. Provide each student with a utensil so that there are at least two different utensils in each group, but only hand out two or three spoons around the class in the first trial. Caution students to use the utensils in the way that was demonstrated so that no student gets injured when using sharp objects. Students must use one hand to hold the utensil; they must use the other hand to hold the beaker on the table in front of them. No lifting or tilting of the beaker is allowed (to reduce giving students an advantage).
3. Tell students that there will be four feeding times (trials), and that each foofoo must eat at least 20 beans to survive. Signal the start and end times of each trial. Students use their utensils to pick up beans from the tray and deposit them into their beaker/dish.
4. For the first trial, give students one minute to pick up the beans. Discuss with students the results of the trial and relate the results to competition, variation, and adaptation.

5. If any foofoos die, students can play the offspring of surviving foofoos. Discuss reproductive success of survivors with students. Give students whose foofoos died spoons or tweezers for the next round.
6. Run three more trials, one of 45 seconds, one of 30 seconds, and one of 15 seconds. At the end of the four trials, the only surviving foofoos will probably be the spoon-mouthed ones. Review the process of natural selection and extinction with students as related to their foofoos.

Analysis and Conclusions

1. Which type of foofoo was the best adapted to its environment? Explain your answer.

   The spoon-mouthed foofoos were best adapted as they were able to survive and reproduce.

2. How does the type of mouth part affect the survival rate of foofoos?

   The foofoos that pick up the most food the fastest are the ones that survive. They are able to outcompete the other foofoos for food.

3. What happens to the foofoos that cannot compete well with other foofoos? Explain.

   The foofoos that cannot compete will die because they cannot get enough food.

4. How does the foofoo scenario model natural selection?

   The best adapted foofoos (spoon-mouthed) survive and reproduce. They are more fit/better adapted (survival of the fittest). The foofoos that are less fit/adapted die and do not reproduce. They become extinct.

Appendix 3.6: Adaptation (Teacher Background)

An *adaptation* is a variation that allows an organism to be better suited to its environment. Organisms that are better adapted to their environment are more "fit," thereby increasing their chance of survival and successful reproduction. Thus, adaptations are the result of natural selection.

Adaptations can be classified as behavioural, physiological, or structural. *Behavioural adaptations* are associated with how organisms respond to their environment. Examples of ways in which organisms have adapted their behaviour are seasonal migration by monarch butterflies, birds, and caribou; hibernation by bears and garter snakes; the bending of sunflowers toward the sun; and the shedding of leaves in the fall by deciduous trees.

Variations in the metabolic processes of organisms across a species are known as *physiological adaptations*. Antibiotic-resistant bacteria and pesticide-resistant insects developed because some organisms developed adaptations that allowed them to survive in the presence of antibiotics and pesticides.

Structural adaptations affect the shape or arrangement of physical features of organisms. For example, the blowholes of whales and dolphins are relocated nostrils, while the needles of a cactus are modified leaves that both protect the plant and reduce water loss.

Mimicry is one type of structural adaptation that allows one species to resemble another. The large (up to 75 mm) caterpillar larva of the elephant hawk-moth defends itself by mimicking a snake. The swollen segments near the head contain two large "eye spots" that fool insectivorous birds (and people) into thinking it is dangerous.

Camouflage is another type of structural adaptation to the appearance of organisms. Such an adaptation assists organisms to survive by allowing them to blend in with their environments. The stick insects resemble the shrub branches they inhabit. The stripes on tigers help them to blend in to the jungle.

Appendix 3.7: Natural Selection in a Candy Dish (Teacher Background)*

Overview

In this lab activity, students become unwitting subjects in a demonstration about natural selection. Students select candies from a bowl and have the opportunity to think about what brought about the "survival" of some candies. This situation is, of course, artificial both in the sense that the selecting is done by people and the "organisms" being selected are non-living entities with no DNA and no ability to reproduce.

Materials

- large candy dish or bowl
- variety of candies of different shapes, sizes, brand names, flavours, and colours (Note: There should be at least 2 popular candies for each student and plenty of unpopular ones. Be aware of any food allergies students may have.)

Teacher Preparation

- Prepare a list of candies and note their initial quantity in the dish.

Procedure

1. Make the candy dish accessible in advance of the lab activity so students can pick candies over a period of time, or the dish can be passed around the room a few times. You can avoid commenting about it at all, or you can make innocent remarks about providing a treat for the students.
2. After more than half the candy has been removed, gather the class together. Start the discussion by pointing out that there is often great variation among individuals of animal species. For example, students can look around the room and list the characteristics that vary among humans. Then, ask students why variation is significant. (One reason variation is important is that it allows for differential survival of individuals.)
3. Show them the candy bowl and the remaining candies. Count what candies remain and list them on the board. Ask them whether they remember which candies were originally available. Make a list on the board of the original set of candy.

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* Source: Tang, Carol. "Candy Dish Selection." *UCMP Lessons.* University of California Museum of Paleontology. 20 Nov. 2003. <www.ucmp.berkeley.edu/education/lessons/candy_dish.html> (5 Apr. 2011). Adapted with permission.

4. Now ask students to list the traits of the candy they *selected* from the candy dish (e.g., chocolate flavour, large size, favourite brand). These are the traits that led to the removal of certain candies.
5. Make a list now of the traits of the candies that were *not selected* (e.g., bad flavour, small size). These are the traits that allowed the candies to survive being taken.
6. So, the fact that there were different candies with different traits resulted in some candies being eaten and others surviving. This is what natural selection does with individuals in a population. Each individual has unique traits; some traits help an individual survive and some traits do not.

Extension

Continually add candy into the candy bowl according to the proportions left in the bowl. For example, if, after the first round, all the chocolate candy has disappeared but a lot of green licorice is left, add more green licorice but do not add any more chocolate. This will accentuate the loss of favourite candies and the proliferation of the remaining ones. In addition, this extension will simulate the production of new generations, similar to the evolution of populations over time. Another possibility is that students will take their second choice of candies, simulating the natural situation where predators will start consuming another prey item when their favourite prey item is eliminated.

Appendix 3.8A: Natural Selection in Legocarnivora (BLM)

Introduction

Within any given population there is variation. Each individual differs from all other members of its species; some differ more than others. Some individuals have adaptations that allow them to be better suited to their environment than others. In nature, the most fit (best adapted) individuals survive and reproduce. This is process is known as *natural selection*.

Purpose

In this lab activity, you will use coins and number cubes to simulate natural selection of the best adapted arrangement of wheels on a Legocarnivora for travelling the farthest distance.

Materials (per student group)

- 2 sets of Lego® wheels
- 1 block (2 × 12) of Lego
- 12 blocks (2 × 2) of Lego
- 1 ramp (1 m long)
- 1 six-sided number cube
- 1 coin
- 2 one-metre sticks

Procedure

Part A: Parental Generation

1. Build your parental Legocarnivora. On top of each set of wheels, place two 2 × 2 Lego blocks. Connect the two sets of wheels and blocks with the 2 × 12 block of Lego. Refer to Figure 1.

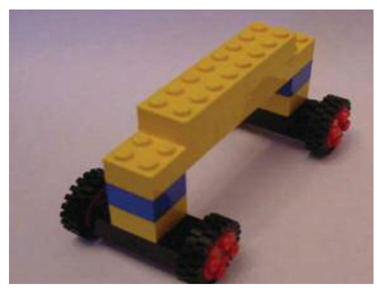

Figure 1: Legocarnivora

2. Set up your test ramp with a 25° to 35° incline. Make sure there is enough room at the bottom of your ramp so that your Legocarnivora can roll up to two metres.
3. Run your parental Legocarnivora down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table.
4. Repeat step 3 for your second trial. Average your results.

Part B: F_1 Generation

1. Your Legocarnivora has three offspring. One is identical to its parent (Offspring A) and the other two are mutations of the parent (Offspring B and Offspring C).
2. Run Offspring A down the ramp (i.e., run the parent again). Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.
3. You will now modify Offspring A to create Offspring B. Flip a coin. If it lands heads up, you will modify the front of the Legocarnivora. If it lands tails up, you will modify the back of the Legocarnivora.
4. Roll a six-sided number cube, and use Table 1: Legocarnivora Modification (see below) to determine how to modify Offspring A to create Offspring B. If at any time the modification is not possible, then your Legocarnivora has "died."

Table 1: Legocarnivora Modification

Cube Roll	Modification
1	add one 2 × 2 block above the wheels
2	add two 2 × 2 blocks above the wheels
3	add three 2 × 2 blocks above the wheels
4	remove one 2 × 2 block from above the wheels
5	remove two 2 × 2 blocks from above the wheels
6	remove three 2 × 2 blocks from above the wheels

5. Build Offspring B and run it down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.
6. Recreate the parental Legocarnivora. Flip the coin and roll the number cube to determine the modifications needed to create Offspring C from the parental Legocarnivora. Refer to Table 1: Legocarnivora Modification.
7. Build Offspring C and run it down the ramp. Measure the distance it rolls from the bottom of the ramp and record this in the Data Table. Repeat for a second trial. Average your results.

Part C: Additional Generations

1. From the three offspring, identify the Legocarnivora that travelled the farthest (on average). This will become the new parent.
2. Repeat steps 1 through 7 of Part B, recording your data for each trial for a total of 10 generations. Note which of your Legocarnivora travels the farthest.
3. Record the mass of your farthest-travelling Legocarnivora.

Observations

Data Table

Legocarnivora	Coin Toss	Cube Roll	# Front Blocks	# Rear Blocks	Distance Rolled		
					Trial 1	Trial 2	Mean
Parent	N/A	N/A	2	2			
Generation 1							
Offspring A							
Offspring B							
Offspring C							
Generation 2							
Offspring A							
Offspring B							
Offspring C							
Generation 3							
Offspring A							
Offspring B							
Offspring C							
Generation 4							
Offspring A							
Offspring B							
Offspring C							
Generation 5							
Offspring A							
Offspring B							
Offspring C							
Generation 6							
Offspring A							
Offspring B							
Offspring C							
Generation 7							
Offspring A							
Offspring B							
Offspring C							
Generation 8							
Offspring A							
Offspring B							
Offspring C							
Generation 9							
Offspring A							
Offspring B							
Offspring C							
Generation 10							
Offspring A							
Offspring B							
Offspring C							

Mass of farthest-travelling Legocarnivora ___________________

Analysis and Conclusions

1. a) Which arrangement of wheels produced the Legocarnivora that travelled the farthest? This is the optimum design.
   b) In which generation did this occur?
2. Is this what you expected to occur? Why or why not?
3. What factor(s) do you think affect the distance the Legocarnivora will travel?
4. a) Of the factor(s) identified, which is environmental in nature?
   b) What effect would a change in the environmental factor have on the optimum design of the Legocarnivora?
   c) Design an experiment to test your prediction.
5. a) Suppose the parent selected in each generation was the one that travelled the shortest distance. How would this affect the optimum design of the Legocarnivora?
   b) Design an experiment to test your prediction.
6. Why were you using the Legocarnivora that travelled the farthest as the new parent for the next generation?
7. Did any of your Legocarnivora die? How is the death of your Legocarnivora an analogy for what happens in nature?
8. How does variation provide the raw material for natural selection?

Appendix 3.8B: Natural Selection in Legocarnivora (Answer Key)

Analysis and Conclusions

1. a) Which arrangement of wheels produced the Legocarnivora that travelled the furthest? This is the optimum design.

   The farthest-travelling Legocarnivora will generally have more blocks on the front than on the rear, or more blocks on the rear than on the front.

   b) In which generation did this occur?

   Answers will vary. The arrangement will usually be in a later generation.

2. Is this what you expected to occur? Why or why not?

   Answers will vary.

3. What factor(s) do you think affect the distance the Legocarnivora will travel?

   The mass of the Legocarnivora and the angle of the ramp will affect the distance travelled.

4. a) Of the factor(s) identified, which is environmental in nature?

   The environmental factor is the angle of the ramp.

   b) What effect would a change in the environmental factor have on the optimum design of the Legocarnivora?

   Answers will vary.

   c) Design an experiment to test your prediction.

   The experimental design should include changing the angle of the ramp and running the experiment again for a few generations.

5. a) Suppose the parent selected in each generation was the one that travelled the shortest distance. How would this affect the optimum design of the Legocarnivora?

   Answers will vary.

   b) Design an experiment to test your prediction.

   The experimental design should include running the experiment again for a few generations, but selecting for the Legocarnivora travelling the shortest distance.

6. Why were you using the Legocarnivora that travelled the farthest as the new parent for the next generation?

   In nature, the best adapted survive and reproduce. The Legocarnivora that travelled the furthest in each generation was the one that was selected for. It was best adapted, so it was the one that "reproduced."

7. Did any of your Legocarnivora die? How is the death of your Legocarnivora an analogy for what happens in nature?

   Yes, some Legocarnivora died. Answers will vary, but should indicate that in nature, sometimes mutations cause variations that are not favourable to the survival of an organism.

8. How does variation provide the raw material for natural selection?

   Individuals with variations that make them better adapted to their environment survive and reproduce in greater numbers than those without such adaptations. Over generations, the number of individuals in a population with the favourable adaptation will increase.

Appendix 3.9: Effects of Selection on Variation (Teacher Background)

Stabilizing selection favours individuals with an "average" value for a trait, and selects against those with extreme values. Note that stabilizing selection tends to keep allele frequencies relatively constant, thereby limiting evolution. In this way, species such as the cockroach and shark have remained stable for millions of years. Human birth weight is an example of stabilizing selection. Until recent medical advances, infants who were too small tended not to survive and infants who were too large died during birth.

Directional selection favours individuals possessing values for a trait at one extreme of the distribution, and selects against the average and the other extreme. Directional selection often operates when an environmental change favours an extreme phenotype. The progressive change in coloration of peppered moths in Great Britain occurred as a result of air pollution (industrial melanism). Over time, the allele frequency for the darker form of the peppered moth increased in the population. The development of antibiotic-resistant bacteria is another example of directional selection. Only those bacteria that can tolerate the presence of an antibiotic survive.

Disruptive selection favours individuals at both ends of the distribution and selects against the average. It is also known as *diversifying selection*. Disruptive selection leads to the formation of distinct subpopulations of organisms. In time, the allele frequencies in the subpopulations may change to the extent that the two groups may no longer be able to interbreed. Marine organisms known as limpets have shell colours that range from white to dark brown. The dark-coloured limpets attached to dark-coloured rocks in the ocean and the light-coloured limpets attached to light-coloured rocks tend to be less visible to predators and have a higher survival rate. The intermediate-coloured limpets (tan coloured) are highly visible to predators and are consumed. The intermediate colour is, therefore, being selected against.

Appendix 3.10A: Investigating Variation (BLM)

Introduction

Many traits have variations within a population. Some variations may increase or decrease an organism's chance of survival in an environment. Natural selection acts upon variation. If a variation helps an organism to survive, the organism is likely to reproduce and pass the variation on to its offspring. Unfavourable variations disappear, because the organisms do not survive to pass the variation to future generations.

Purpose

In this investigation, you will examine variation in the length of dried beans.

Materials (per group)

- 50 dried beans
- ruler with millimetre markings

Procedure

1. Obtain a sample of 50 dried beans. Identify the largest and smallest beans in the sample.
2. Measure the length of the smallest bean to the nearest millimetre. Record its length in the first row of the length column and add a tally mark on the Data Table.
3. Measure the length of the largest bean to the nearest millimetre. In the length column of the Data Table, write the intermediate bean lengths. Then record the length of the largest bean in the final row of the length column and add a tally mark.
4. Measure and tally the remaining 48 beans in your sample.
5. Count the tally marks for each length and record the amount in the group total column.
6. Determine the class total for each length and record the amount in the class total column.

Data Table

Length (mm)	Tally	Group Total	Class Total

Analysis and Conclusions

1. Was there variation in the length of your dried beans? Use specific data to support your answer.
2. Prepare a histogram of the class results. Plot the class total on the y-axis and the length on the x-axis.
3. How would you describe the shape of the graph?
4. What advantage is there for using the class results rather than your group results?
5. What disadvantage could longer length give to the survival of the bean?
6. What disadvantage could shorter length give to the survival of the bean?
7. Complete the following sentence:
   According to the histogram of bean seed length, as the amount of variation from the average length increases, the frequency of that variation _________.
8. If larger bean seeds were a selective advantage, would this be stabilizing, directional, or disruptive selection? Explain.

Appendix 3.10B: Investigating Variation (Answer Key)

Analysis and Conclusions

1. Was there variation in the length of your dried beans? Use specific data to support your answer.

   Yes, there was variation in the length of the beans. Specific examples will vary.

2. Prepare a histogram of the class results. Plot the class total on the *y*-axis and the length on the *x*-axis.

   Results will vary from class to class, but generally a bell-shaped curve will result.

3. How would you describe the shape of the graph?

   The result is a bell-shaped curve.

4. What advantage is there for using the class results rather than your group results?

   Using class data gives a larger sample size, which statistically gives a more accurate result.

5. What disadvantage could longer length give to the survival of the bean?

   Larger beans can be found more easily by birds and rodents, and could be eaten.

6. What disadvantage could shorter length give to the survival of the bean?

   Smaller beans may not contain enough food for the germinating embryo.

7. Complete the following sentence:

   According to the histogram of bean seed length, as the amount of variation from the average length increases, the frequency of that variation *decreases*.

8. If larger bean seeds were a selective advantage, would this be stabilizing, directional, or disruptive selection? Explain.

   This would be directional selection. Individuals at one extreme of the distribution are favoured—large seeds are favoured over medium and small seeds. Over time, there would be more and more large seeds, and fewer medium and small seeds.

Appendix 3.11A: Where Did All the Four-Leaf Clovers Go?—Case Study (BLM)

Part A: Introduction

A team of biologists was conducting a long-term study of wildflower distribution in a meadow in a provincial park. A variety of wildflower species were present, such as white clover (*Trifolium repens*), columbine (*Aquilegia canadensis*), and harebell (*Campanula rotundifolia*). During the initial sampling of the plant populations, the biologists noted that the white clovers were usually of the three-leaf variety, but occasionally some four-leaf clovers were found. Four-leaf clovers are a naturally occurring variation of the three-leaf type. Two-leaf and five-leaf variations also occur, but these are extremely rare.

One year, the Parks Branch decided to create a new picnic area near the study site. Over the course of several years, the team of biologists noted that the wildflower population in the study area began to change. As more people began to visit the meadow, the number of four-leaf clovers began to decline to the point that they had virtually disappeared from the site. The research team was puzzled. Where did all the four-leaf clovers go?

Part A: Questions

1. What do you think has happened to the four-leaf clovers?
2. Can you design an investigation to test your hypothesis?

Part B: Mystery Solved

The research team determined that the four-leaf clovers had been picked by the picnickers over several years. The team had fenced in an area to protect the clover from tourists, but even then, the four-leaf variety was found on extremely rare occasions. The collecting had taken its toll. In the meadow, it was maladaptive to be four-leafed, but the three-leaf clovers were left alone.

Part B: Questions

1. What happened to the gene pool of the clover to explain why the four-leaf variety almost disappeared?
2. Which type of selection was occurring in the meadow? Explain your answer.
3. Sketch a graph showing the initial distribution of leaf variation in *Trifolium repens*. Indicate the number of leaves on the x-axis, and the number of plants on the y-axis.
4. Sketch a graph showing the leaf variation in *Trifolium repens* several years later. Indicate the number of leaves on the x-axis, and the number of plants on the y-axis.

Appendix 3.11B: Where Did All the Four-Leaf Clovers Go?— Case Study (Answer Key)

Part A

1. The four-leaf clovers were being picked by the picnickers.
2. Possible answers could include interviewing picnickers to see whether they are picking the clovers; enclosing an area in the meadow with a fence to prevent the tourists from getting at the clover and see whether the four-leaf type returns; and putting in a video camera to record the picnickers' behaviours.

Part B

1. The clover gene pool gradually changed in favour of the three-leaf type.
2. Artificial selection was taking place. The normal three-leaf type was being selected for, and the extreme variation (four-leaf) type was being selected against.
3. The frequency peaks at the three-leaf variety, and curves indicate some of the four-leaf variety and very few of the two- and five-leaf varieties.
4. The frequency peaks at the three-leaf variety, and now shows only a few of the four-leaf variety, and very few of the two- and five-leaf varieties.

Appendix 3.12A: Population Genetics Calculations (BLM)

In a stable population, the frequency alleles in a population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele

q = frequency of the recessive allele

The Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$) allows us to calculate the frequencies of the three genotypes, where

p^2 = frequency of individuals homozygous for the dominant allele

q^2 = frequency of individuals homozygous for the recessive allele

$2pq$ = frequency of individuals heterozygous genotype

1. A population of mice has a gene made of 90% *M* alleles (black fur) and 10% *m* alleles (grey fur).
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) If there are 500 mice in the population, how many will have grey fur?
   c) If there are 500 mice in the population, how many will be homozygous for black fur?

2. While studying a sample of pea plants, you find that 36 of 400 plants are short (recessive). The rest of the plants are tall.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) Determine the number of heterozygous pea plants present.
   c) Determine the number of homozygous tall pea plants present.

3. The ability to taste PTC (a chemical) is caused by a dominant gene. In a test of 2000 people, 720 people cannot taste the chemical.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	$q =$	
Dominant allele	$p =$	
Homozygous recessive	$q^2 =$	
Homozygous dominant	$p^2 =$	
Heterozygous	$2pq =$	

   b) How many of the 2000 people are homozygous dominant?
   c) How many of the 2000 people are heterozygous?
   d) What is the frequency of the recessive allele?
   e) What is the frequency of the dominant allele?

4. In a population, 64% of individuals show the recessive trait.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	$q =$	
Dominant allele	$p =$	
Homozygous recessive	$q^2 =$	
Homozygous dominant	$p^2 =$	
Heterozygous	$2pq =$	

   b) If the population has 10,000 individuals, how many show the recessive trait?
   c) If the population has 10,000 individuals, how many show the dominant trait?

5. The frequency of a recessive disorder is 4% in a population.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	
Dominant allele	p =	
Homozygous recessive	q^2 =	
Homozygous dominant	p^2 =	
Heterozygous	$2pq$ =	

   b) What percentage of the population carries the recessive gene?
   c) What percentage of the population is homozygous dominant?

Appendix 3.12B:
Population Genetics Calculations (Answer Key)

In a stable population, the frequency alleles in a population will equal to 1. This can be expressed as $p + q = 1$, where

p = frequency of the dominant allele

q = frequency of the recessive allele

The Hardy-Weinberg principle equation ($p^2 + 2pq + q^2 = 1$) allows us to calculate the frequencies of the three genotypes, where

p^2 = frequency of individuals homozygous for the dominant allele

q^2 = frequency of individuals homozygous for the recessive allele

$2pq$ = frequency of individuals heterozygous genotype

1. A population of mice has a gene made of 90% *M* alleles (black fur) and 10% *m* alleles (grey fur).

   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.10
Dominant allele	p =	0.90
Homozygous recessive	q^2 =	0.01
Homozygous dominant	p^2 =	0.81
Heterozygous	$2pq$ =	0.18

   b) If there are 500 mice in the population, how many will have grey fur?

   0.01 × 500 = 5 mice with grey fur

   c) If there are 500 mice in the population, how many will be homozygous for black fur?

   0.81 × 500 = 405 mice homozygous for black fur

2. While studying a sample of pea plants, you find that 36 of 400 plants are short (recessive). The rest of the plants are tall.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.30
Dominant allele	p =	0.70
Homozygous recessive	q^2 =	0.09
Homozygous dominant	p^2 =	0.49
Heterozygous	$2pq$ =	0.42

   b) Determine the number of heterozygous pea plants present.
   0.42 × 400 = 168 heterozygous pea plants
   c) Determine the number of homozygous tall pea plants present.
   0.49 × 400 = 196 homozygous tall pea plants

3. The ability to taste PTC (a chemical) is caused by a dominant gene. In a test of 2000 people, 720 people cannot taste the chemical.
   a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.60
Dominant allele	p =	0.40
Homozygous recessive	q^2 =	0.36
Homozygous dominant	p^2 =	0.16
Heterozygous	$2pq$ =	0.48

   b) How many of the 2000 people are homozygous dominant?
   0.16 × 2000 = 320 people are homozygous dominant.
   c) How many of the 2000 people are heterozygous?
   0.48 × 2000 = 960 people are heterozygous
   d) What is the frequency of the recessive allele?
   60%
   e) What is the frequency of the dominant allele?
   40%

4. In a population, 64% of individuals show the recessive trait.

a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.80
Dominant allele	p =	0.20
Homozygous recessive	q^2 =	0.64
Homozygous dominant	p^2 =	0.04
Heterozygous	$2pq$ =	0.32

b) If the population has 10,000 individuals, how many show the recessive trait?

0.64 × 10,000 = 6400 show the recessive trait

c) If the population has 10,000 individuals, how many show the dominant trait?

10,000 – 6400 = 3600 show the dominant trait

5. The frequency of a recessive disorder is 4% in a population.

a) Use the Hardy-Weinberg principle equation to complete the following chart.

Recessive allele	q =	0.20
Dominant allele	p =	0.80
Homozygous recessive	q^2 =	0.04
Homozygous dominant	p^2 =	0.64
Heterozygous	$2pq$ =	0.32

b) What percentage of the population carries the recessive gene?

32%

c) What percentage of the population is homozygous dominant?

64%

Appendix 3.13A: Using the Hardy-Weinberg Principle Equation—Investigation (BLM)

Introduction

The Hardy-Weinberg principle equation, expressed as $p^2 + 2pq + q^2 = 1$, allows the calculation of allele and genotype frequencies in a population. In this investigation, you will determine allele and genotype frequencies for a single human trait.

Purpose

In this investigation, you will calculate the frequencies of the dominant and recessive alleles for an inherited trait. You will also compare the frequencies of two alleles with the frequencies of their phenotypes.

Materials

- calculator

Procedure

1. Tongue rolling is controlled by a single gene. Persons homozygous dominant or heterozygous for this trait can roll their tongues. Homozygous recessive persons cannot roll their tongues. Determine whether you can roll your tongue.
2. Indicate your phenotype (tongue roller or non-roller) on the classroom board. Record the class total of rollers and non-rollers in Data Table 1.
3. From the class data, calculate q^2, the fraction of students with the homozygous recessive genotype. This is the number of non-rollers divided by the total number of students in the sample. Record this in Data Table 2.
4. Calculate q, the frequency of the recessive allele, by taking the square root of q^2. Record this in Data Table 2.
5. Determine the frequency of the dominant allele, p, using the formula $p = 1 – q$. Record this in Data Table 2.
6. Calculate p^2, the proportion of students with the homozygous genotype. Record this in Data Table 2.
7. Calculate $2pq$, the proportion of students with the heterozygous genotype. Record this in Data Table 2.

Data Table 1

Total Number of Rollers	**Total Number of Non-Rollers**

Data Table 2

Proportion with homozygous recessive genotype (q^2)	
Frequency of recessive allele (q)	
Frequency of dominant allele (p)	
Proportion with homozygous dominant genotype (p^2)	
Proportion with heterozygous genotype ($2pq$)	

Analysis and Conclusions

1. What are the frequencies of the alleles that affect tongue rolling in students in the class?
2. a) Is q, the frequency of the recessive allele, larger or smaller than the frequency of people showing the recessive trait?
   b) Why do you think this is so?
3. If you tested 10,000 people, do you think the genotype frequencies in this population would be the same as those in this class? Explain.
4. If all the Hardy-Weinberg principle conditions were met, what would be the next generation's allele frequencies?
5. *Evolution* is sometimes defined as a change in the allele frequency in a population's gene pool. What does this mean?

Appendix 3.13B: Using the Hardy-Weinberg Principle Equation—Investigation (Answer Key)

Analysis and Conclusions

1. What are the frequencies of the alleles that affect tongue rolling in students in the class?

   Answers will vary. See Data Table 2.

2. a) Is q, the frequency of the recessive allele, larger or smaller than the frequency of people showing the recessive trait?

   The frequency of the recessive allele (q) is larger than the frequency of people showing the recessive trait (q^2).

   b) Why do you think this is so?

   If a person has one copy of the recessive allele and one copy of the dominant allele (is heterozygous for the trait), he or she will show the dominant trait. A person must have two copies of the recessive allele to show the recessive trait. Therefore, the frequency of q is composed of people who are heterozygous for the trait and homozygous recessive for the trait.

3. If you tested 10,000 people, do you think the genotype frequencies in this population would be the same as those in this class? Explain.

   It is unlikely that the genotype frequencies would be identical. The larger sample size would be the better representation of the gene pool.

4. If all the Hardy-Weinberg principle conditions were met, what would be the next generation's allele frequencies?

   The allele frequencies would remain the same. The population would be in genetic equilibrium.

5. *Evolution* is sometimes defined as a change in the allele frequency in a population's gene pool. What does this mean?

   This means that when the types of genes and their occurrence in the gene pool change over time, evolution is taking place.

Appendix 3.14A: Population Bottlenecks and Endangered Species—Case Study (BLM)

Introduction

The whooping crane (*Grus americana*) is the tallest bird in North America, standing almost 1.5 m in height, with a wingspan of up to 2.5 m. While populations of "whoopers" were never large, their numbers declined rapidly in the early 1900s from hunting and habitat destruction due to agriculture. In 1941, only about 21 wild whooping cranes were left in the world—15 migrating birds that nested in the Wood Buffalo National Park of the Northwest Territories and six non-migrating birds that died in a storm in 1949. In the 1940s, various agencies in Canada and the United States of America joined together in an effort to save the birds from extinction.

Wildlife refuges and national parks now protect the whooping crane's natural summer breeding area in the Northwest Territories and wintering grounds in coastal Texas. Captive breeding programs have been established in some zoos (including the Calgary Zoo). Other flocks have been established in Florida (non-migratory) and Wisconsin (migratory). By the winter of 2008/2009, the whooping crane population had climbed to 534 captive and wild birds, 247 of which nested in Wood Buffalo National Park. All the Wood Buffalo birds today are descended from the 15 migratory birds of 1941.

Conservation efforts are hampered by a number of factors. About 15 percent of eggs laid in the wild are infertile, possibly as a result of inbreeding. Disease is a problem in some captive breeding populations. Severe climatic events, including hurricanes in Texas and late-spring blizzards in the Northwest Territories breeding grounds, can lead to increased mortality. Predation of newly hatched chicks is always a threat. Power lines and cell towers pose hazards during migration. Habitat disturbance in the Texas wintering grounds is an ongoing concern due to shipping and oil exploration and development. While their numbers have increased through conservation efforts, whooping cranes will continue to be vulnerable due to the small population size.

Questions

1. Whooping cranes are an example of an endangered species that has passed through a population bottleneck. Explain how a population bottleneck can alter the genetic variation in the gene pool of a species.
2. Describe the effect of the population bottleneck on the potential of the whooping cranes to adapt to environmental changes and evolve.
3. How could the population bottleneck affect the ability of the whooping cranes to recover from near extinction?
4. Why should we protect and conserve an endangered species?

References

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Appendix 3.14B: Population Bottlenecks and Endangered Species—Case Study (Answer Key)

1. Whooping cranes are an example of an endangered species that has passed through a population bottleneck. Explain how a population bottleneck can alter the genetic variation in the gene pool of a species.

   Because the population reaches such a low number of individuals in a population bottleneck, only a few individuals contribute genes to the entire future population of the species. Much genetic variation within the species is lost, and allelic frequencies change significantly in the remaining gene pool.

2. Describe the effect of the population bottleneck on the potential of the whooping cranes to adapt to environmental changes and evolve.

   The lack of genetic variation reduces the ability of the whooping cranes to adapt to environmental changes. There is little variation upon which natural selection can act.

3. How could the population bottleneck affect the ability of the whooping cranes to recover from near extinction?

   No matter how many whooping cranes there are, the species will always be at risk of extinction. Their genetic homogeneity makes them potentially more sensitive to disease and genetic conditions associated with inbreeding.

4. Why should we protect and conserve an endangered species?

   Answers may vary. They may include points such as the following:

   - *Humans caused the whooping crane numbers to decline by hunting them and destroying their habitat.*
   - *Our actions caused the whooping crane's gene pool to become a gene puddle.*
   - *The human population has become so large and is consuming so many resources that we are forcing our neighbours out of their homes.*
   - *We should practise good stewardship and preserve our world for future generations.*