UNIT 4:
ORGANIZING BIODIVERSITY

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Unit 4: Organizing Biodiversity

Specific Learning Outcomes

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

SLO: B12-4-01
SLO: B12-4-02

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students developed an appreciation for the diversity of living things. They provided examples of a variety of animals (vertebrate and invertebrate) to illustrate their diversity, and observed and described the diversity of living things within the local environment.

Students investigated the complex interactions between organisms and their environment in Grade 7 Science. They defined ecosystem and provided examples of a range of ecosystems.

In Grade 10 Science, students examined the relationships present in ecosystems to investigate issues related to sustainability, and explored the concepts and implications of species biodiversity. They observed and documented a range of organisms that illustrate the biodiversity of a local or regional ecosystem, and explained how the biodiversity of an ecosystem contributes to its sustainability.

TEACHER NOTE

Biodiversity can be defined as the range of life in an area. It includes not only the diversity among species, but also the diversity within a species. Review with students the importance of genetic diversity (variation) within a species and the importance of biodiversity to ecosystems. Students will be familiar with the term *species*, but may not have explored the topic in depth.

ACTIVATE

Sticky-Note Ecosystems

Divide the class into small groups of two to four students and provide each group with a small package of sticky notes. Give students two minutes to brainstorm and record the names of as many types of organisms as possible, writing the name of one organism per sticky note. Students should try to give as specific a name as possible (e.g., beluga whale instead of whale, bald eagle instead of bird, elm instead of tree). Ask students to include various types of organisms (e.g., plants, animals, fungi) from different ecosystems. If students do not know the name of an organism, they can describe it.

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

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

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

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

List different types of ecosystems on the board (e.g., lake, urban, boreal forest). Then ask students to group their organisms according to the ecosystems in which they would be found. Each group then posts their organisms in the appropriate ecosystem.

Examine the sticky-note ecosystems with the class and pose questions such as the following:

- Are any organisms found in more than one ecosystem?
- Which types of organisms are not represented in your ecosystems (e.g., decomposers, producers, consumers)?
- How diverse are your ecosystems? (How many different species are found in your ecosystems?) Relate this to biodiversity.
- Would there be diversity in each of the types of organisms you have listed? Explain. (Yes, there would be genetic diversity.)

ACQUIRE/APPLY

First Word (U2)

Review with students the meaning of the term *biodiversity*, and have them write the word vertically down a page in their notebooks. Students then construct statements about biodiversity that begin with each letter in the word to develop an acrostic.

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Example

Biodiversity is the range of life in an area.
I
O
D
I
Variation is the source of genetic diversity.
E
R
Species are organisms that share a common gene pool.
I
T
Y

Suggestion for Assessment

Scan the First Word acrostics to determine what students already know (content and terminology), and identify any misconceptions that students may have. The information can be used to plan instruction (formative assessment). The acrostics can be saved for analysis and reflection at the end of the unit. (See Last Word, learning outcome B12-4-07.)

Biodiversity—Concept Overview (U1)

Graphic organizers enhance students' learning, as they assist students in clarifying their thinking. Have students complete a Concept Overview for the concept of biodiversity. For more information, refer to *SYSTH* (pp. 11.22–11.25, 11.37).

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

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

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

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

Suggestion for Assessment

Completed Concept Overviews 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).

Definition of a Species—Class Discussion (U2, N3)

Provide students with pictures of the eastern meadowlark and the western meadowlark. Ask them whether they think the two birds are members of the same species or are different species. While the two birds may look the same, they are, in fact, two different species. The eastern meadowlark (*Sturnella magna*) lives in eastern Canada, while the western meadowlark (*Sturnella neglecta*) lives in the Prairie provinces. Discuss with students the difficulties in determining the definition of a species (i.e., hybrids, phenotypic variation within a species, non-interbreeding subpopulations). For more information, refer to Appendix 4.1: Definition of a Species (Teacher Background).

Resource Links

- Encyclopedia of Life. Home Page. <www.eol.org/>.
  This is an online reference and database of all currently known species.
- Tree of Life Web Project. Home Page. <www.tolweb.org/tree/>.
  Refer to this website for information about biodiversity, characteristics of different groups of organisms, and their evolutionary history.

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Suggestion for Assessment

Ask students to complete a Two-Minute Paper in the last few minutes of the class. Provide them with two questions to respond to, and have them record their individual responses on a piece of paper.

Questions could include the following (Keeley):

- What was the most important thing you learned today?
- What did you learn today that you didn't know before class?
- What important question remains unanswered for you?
- What would help you to learn better tomorrow?

Review students' responses, looking for areas of confusion, and address the questions during the next class (formative assessment).

Something's Fishy in Paxton Lake: Speciation in Sticklebacks—Case Study (U2, S1, G1, G2, G3)

In the case study "Something's Fishy in Paxton Lake: Speciation in Sticklebacks" by Joan Sharp (available on the National Center for Case Study Teaching in Science website), students work in groups to decide whether two populations of sticklebacks represent separate species. Encourage students to use effective reading strategies to acquire new knowledge and information from the text when reading a case study. 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.

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

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

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

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

Resource Links

- 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.

- Sharp, Joan. "Something's Fishy in Paxton Lake: Speciation in Sticklebacks." *Back Catalog*. National Center for Case Study Teaching in Science. 2 Nov. 2001. <http://ublib.buffalo.edu/libraries/projects/cases/stickleback/stickleback.html>. Case Teaching Notes are available at <http://ublib.buffalo.edu/libraries/projects/cases/stickleback/stickleback_notes.html>.

Suggestion for Assessment

Whatever the form of assessment used, students should be made aware of the criteria beforehand. Answers to the exercises can be assessed by the teacher, or shared and discussed with other students/groups (peer assessed). For more information on peer assessment, refer to Appendix 4.2A: Peer Assessment (Teacher Background) and Appendix 4.2B: Guidelines for Peer Assessment (BLM).

DEFINING BIODIVERSITY AND SPECIES

SPECIFIC LEARNING OUTCOMES

B12-4-01: Define the concept of biodiversity in terms of ecosystem, species, and genetic diversity. (GLOs: D2, E1)

B12-4-02: Explain why it is difficult to determine a definition of *species*. (GLOs: A1, E1)

Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding subpopulations . . .

Biodiversity—Demonstrating Understanding (U1, N3)

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

- Why can it be difficult to define what a species is?
- What is the difference between biodiversity and genetic diversity?

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 a particular lesson.

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

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

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

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

NOTES

CLASSIFYING ORGANISMS

SPECIFIC LEARNING OUTCOME

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

SLO: B12-4-03

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students were introduced to classification systems, and they constructed and used their own systems, as well as those developed by others. In doing so, students learned to recognize the advantages and disadvantages of classification systems in organizing information.

TEACHER NOTE

Great progress has been made in the last several decades in clarifying evolutionary relationships among living things. Some of the information presented in textbooks is in conflict with the more recent revisions to the tree of life.

Students will be most familiar with traditional systematics (Linnaean classification) of organisms. This method classifies organisms into taxa (groups) using morphological and physiological similarities, but does not fully reconstruct evolutionary relationships among organisms. For example, birds and dinosaurs are organized into separate classes (Aves and Reptilia).

Introduce students to *phylogenetic systematics (cladistics)*, a method developed by German biologist Willi Hennig (1913–1976). This method uses phylogenetics as the determining factor in classification, emphasizing descent and common ancestry in order to determine the evolutionary history of groups of organisms. *Cladograms* are diagrams that show evolutionary relationships based on shared inherited features, and do not rank organisms into phyla, class, order, and so on. Organisms are organized in *clades*, groups of organisms that include an ancestor and all descendents of that ancestor. As a result, birds are placed in the same clade as dinosaurs (*Dinosauria*) as they share a common ancestor.

Note that the shift to phylogenetic systematics is in progress. The Linnaean classification system is still used in many textbooks. Diagrams of phylogenetic trees, evolutionary trees, or the tree of life may or may not be true cladograms.

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

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)

BACKGROUND INFORMATION

- *Classification* is a general term for grouping things in an organizational scheme.
- *Taxonomy* is the science of naming life forms.
- *Phylogenetics* is the process of determining the evolutionary history and relationships among the various forms of life through time.
- *Systematics* deals with the diversity of life and the relationships among life forms, both living and extinct. New information obtained from DNA and RNA sequencing has led to sweeping changes in the classification of organisms since 1990.
- *Traditional systematics* (Linnaean classification), based on morphological differences between groups, is being replaced by *phylogenetic systematics* (cladistics), which reflects evolutionary relationships. Traditional groupings such as family and class are falling out of use.

For more information on the dynamic nature of classification as an example of how the use of new and improved technologies have led to changes in the entire system of classification, refer to Appendix 4.3: The Changing Nature of Classification (Teacher Background).

Resource Link

- Thanukos, Anastasia. "A Name by Any Other Tree." *Evolution: Education and Outreach* 2.2 (2009): 303–09. Available on the SpringerLink website at <www.springerlink.com/content/k176638503p63017/fulltext.pdf>.

  This article discusses the changing nature of classification to show evolutionary relationships.

CLASSIFYING ORGANISMS

SPECIFIC LEARNING OUTCOME

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

ACTIVATE

Think-Pair-Share

Pose the following question to students:

> Think about your home, school, and neighbourhood. Can you think of any examples of classification systems in use in your home, school, or environment?

Give students time to think of examples individually. Students then pair up with a partner to discuss their ideas.

Examples of classification systems may include the following:

- library (e.g., Dewey decimal system)
- grocery store (e.g., aisles, departments)
- DVD rental shop (e.g., alphabetical order)
- students in school (e.g., grades)
- clothing at home (e.g., sock drawer, shirt drawer)

ACQUIRE/APPLY

Species and Systematics—Demonstration (U1)

For this demonstration, use a variety of vegetables to introduce and discuss binomial nomenclature and systematics. Refer to Appendix 4.4: Species and Systematics—Demonstration (Teacher Background).

Critical Thinking (U2)

Categorical logic is the basis for classification systems. It examines relationships according to groups or categories of things. For example, the statement "all dogs are mammals" informs us that the entire group of dogs is contained within the larger group of mammals.

Categorical logic uses deductive reasoning to reach a conclusion. The conclusion is valid only if the evidence provided is true and the reasoning used to reach the conclusion is correct. See Appendix 4.5: Categorical Reasoning in Biology (BLM) for the student learning activity.

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

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)

Suggestion for Assessment

Students can compare their completed work 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). Remind students to talk about the work, not the person, and to make specific suggestions describing what is good about the work and what could be improved.

What Is Cladistics? (U1, N1)

Introduce students to cladistics and cladograms. Cladistics is now accepted as the best method for phylogenetic analysis, as it provides an explicit and testable hypothesis of evolutionary relationships among organisms.

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.

CLASSIFYING ORGANISMS

SPECIFIC LEARNING OUTCOME

B12-4-03: Describe the dynamic nature of classification. (GLOs: A1, A2)

Include: different systems and current debates

Resource Links

- Peabody Museum of Natural History, Yale University. "Travels in the Great Tree of Life." *Online Exhibitions.* <www.peabody.yale.edu/exhibits/treeoflife/learn.html>.
  This tutorial explains the basics of tree thinking and provides many examples from actual organisms.
- University of California Museum of Paleontology. "Journey into Phylogenetic Systematics." *Phylology of Life.* <www.ucmp.berkeley.edu/clad/clad4.html>.
  This website provides an introduction to the philosophy, methodology, and implications of cladistic analysis.
- ———. "Phylogentic Systematics, a.k.a. Evolutionary Trees." *Understanding Evolution.* <http://evolution.berkeley.edu/evolibrary/article/phylogenetics_01>.
  This tutorial provides information on building, reading, and using evolutionary trees (cladograms).
- ———. "What Did T. Rex Taste Like? An Introduction to How Life Is Related." *Education*. <www.ucmp.berkeley.edu/education/students.php>.
  This interactive module provides an introduction to cladistics and involves students in posing hypotheses about past life based upon evolutionary history.

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 students realize that you are taking their responses seriously, and they will respond thoughtfully and with more detail in the future.

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

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)

Compare and Contrast (U2)

Students complete a Compare and Contrast frame comparing and contrasting traditional systematics (Linnaean classification) and phylogenetic systematics (cladistics). Refer to *SYSTH* (pp. 10.15–10.18, 10.24) for more information and a Compare and Contrast frame.

Suggestion for Assessment

Assess students' Compare and Contrast frames for conceptual understanding, and provide descriptive feedback as to how the frames could be improved.

Classification Systems—Investigation (P1, S1, I4)

A variety of learning activities are available in lab manuals, in textbooks, and on the Internet for developing and using classification systems. Use imaginary or real organisms (not human-made objects such as nuts and bolts) to reflect how modern classification indicates evolutionary history. Refer to Appendix 1.3: Student Lab Skills (Teacher Background) for information on assessing and evaluating student lab skills.

Suggestion for Assessment

Assess responses of students to determine their levels of conceptual understanding and to guide further teaching/learning activity selection (if needed). Refer to Appendix 1.4A: Lab Skills Checklist—General Skills (BLM) and Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM).

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

SLO: B12-4-04

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students identified, based on evidence gathered by paleontologists, similarities and differences between animals living today and those that lived in the past.

BACKGROUND INFORMATION

Traditional Linnaean classification was based on similarities in morphology among species. It artificially grouped organisms into kingdoms, phyla, and so on, and relied on the fossil record, homologies, and embryology to determine relationships between organisms.

Phylogenetic classification (cladistics) uses shared characteristics to attempt to understand evolutionary relationships among organisms. It is now the accepted method for systematic analysis as it is based on ancestor and descent relationships (phylogeny). DNA sequencing and RNA sequencing are important techniques for determining phylogenetic relationships.

ACTIVATE

Class Survey

Pose the following question to students:

- Science textbooks often have tree- or fan-like diagrams showing different groups of organisms. What types of evidence do scientists use to classify organisms and determine evolutionary relationships?

Ask students to share their ideas in class and record their responses on the board. Use the responses to lead students in a discussion of evidence used to classify organisms and determine evolutionary relationships.

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

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-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)

ACQUIRE/APPLY

Technologies and Tools of Classification—Jigsaw Strategy (U2, I1, I2, I4, G1, G3)

Divide the class into groups, and assign to each group a particular type of evidence used in the science of classification (e.g., fossil dating, DNA analysis). Each group then investigates its classification technology or tool. The groups prepare one-page summaries outlining how their technology or tool is used in classifying organisms and determining phylogenetic relationships.

Using the Jigsaw strategy, arrange students into new groups so that each new group contains one expert from each of the previous groups. Each expert then 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 summary. For more information about the Jigsaw strategy, see *SYSTH* (p. 3.20).

Suggestion for Assessment

Students can assess their collaborative process. Refer to Appendix 1.13: Collaborative Process—Assessment (BLM).

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

Understanding the Evidence (U1)

The use of videos and computer animations that illustrate and describe the evidence used to classify organisms and determine evolutionary relationships can enhance students' conceptual understanding. A wealth of information can be found in a variety of multimedia formats.

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

- 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.
- University of California Museum of Paleontology. "The Evolution of Flight in Birds." *Education*. <www.ucmp.berkeley.edu/education/students.php>.
  This module examines evidence from the fossil records, behaviour, biomechanics, and cladistic analysis to interpret the sequence of events that led to flight in the dinosaur lineage.
- ———. *Online Exhibits*. <www.ucmp.berkeley.edu/exhibits/index.php>.
  This website features exhibits such as "The Paleontology Portal," "Tour of Geologic Time," "History of Life through Time," and "Education Resources." It also offers a range of interactives, lessons, and learning activities.

Suggestion for Assessment

The use of Note Frames assists teachers in monitoring students' understanding (formative assessment). The information 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).

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

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-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)

Museum—Field Trip (U2, P2, I1)

Students can learn about classifying organisms and determining evolutionary relationships by participating in field trips to the Canadian Fossil Discovery Centre, located in Morden, Manitoba, or The Manitoba Museum, located in Winnipeg.

Resource Links

- Canadian Fossil Discovery Centre. Home Page. <www.discoverfossils.com/>.
  This centre has exhibits of Cretaceous marine fossils, including mosasaurs, plesiosaurs, squid, sharks, and seabirds. A dig can be arranged for students to learn field techniques and search for and excavate fossils.
- The Manitoba Museum. "Earth History Gallery." *Museum*. <www.manitobamuseum.ca/main/museum/earth-history-gallery/>.
  This gallery traces Manitoba's geologic past and has fossils of various life forms such as trilobites and a plesiosaur.

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 have them 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.

DETERMINING EVOLUTIONARY RELATIONSHIPS

SPECIFIC LEARNING OUTCOME

B12-4-04: Describe types of evidence used to classify organisms and determine evolutionary relationships. (GLOs: A2, A5)

Examples: fossil record, DNA analysis, biochemistry, embryology, morphology . . .

Demonstrating Understanding—Are Pigeons Really "Rats with Wings"? (U2)

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

- While pigeons are often mocked as "rats with wings," pigeons (and all birds) are more closely related to carnivorous dinosaurs such as tyrannosauri and velociraptors than they are to mammals. Some have even called birds "dinosaurs with feathers." What evidence is there for the close relationship between birds and reptiles?

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 a particular lesson. Students' responses may include the following:

- fossils (e.g., archaeopteryx)
- dating of fossils (e.g., radioisotopes such as carbon-14)
- similarities in structure (e.g., presence of wishbone, structure of hip bones)
- fossil records (showing changes over time)
- DNA analysis (e.g., avian DNA is more similar to crocodilian DNA than it is to mammalian DNA)

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

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-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)

NOTES

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

SLO: B12-4-05
SLO: B12-4-06

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students identified the five kingdoms (i.e., monerans, protists, fungi, plants, and animals) commonly used for the classification of living things and provided examples of organisms from each kingdom to illustrate the diversity of living things.

TEACHER NOTE

With advances in DNA and RNA sequencing technologies, phylogenetic relationships among organisms are currently subject to intense debate. Extensive changes in classification have been in progress since 1990. These changes can lead to confusion for students when they consult various sources of information. Some textbooks and resources may not provide information about the three-domain classification system, but instead use the five- or six-kingdom system. Other resources may use the term *superkingdom* instead of domain. Consult journals and reputable Internet sites for current information.

BACKGROUND INFORMATION

For more information on the characteristics of the domains of life, refer to Appendix 4.6: The Three Domains of Life (Teacher Background).

Resource Link

- Thanukos, Anastasia. "A Name by Any Other Tree." *Evolution: Education and Outreach 2.2* (2009): 303–309. Available on the SpringerLink website at <www.springerlink.com/content/k176638503p63017/fulltext.pdf>.

  This article discusses the changing nature of classification to show evolutionary relationships.

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-G1: Collaborate with others to achieve group goals and responsibilities. (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)

ACTIVATE

Do You Remember?

Ask students to recall the taxa of Linnaean classification (kingdom, phylum, class, order, family, genus, and species) or the mnemonics used to remember the taxa (e.g., Kings Play Chess On Fuzzy Green Stools, Kids Prefer Chocolate Over Fried Green Spinach). Inform students of the revised classification system that now recognizes three domains, and ask them to create a new mnemonic to help them remember the names of the three domains.

ACQUIRE/APPLY

Domains and Kingdoms (U2)

Discuss with students the characteristics and representative organisms of each domain and kingdom, and explain how genetic and biochemical analyses changed biological classification. The use of diagrams to illustrate and describe the relationship among three domains of living things can assist students.

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.

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

Resource Links

- Tree of Life Web Project. Home Page. <www.tolweb.org/tree/>.
  This website contains information about the diversity of organisms on Earth, including their evolutionary history and characteristics.
- University of California Museum of Paleontology. "History of Life through Time." *Online Exhibits*.
  <www.ucmp.berkeley.edu/exhibits/historyoflife.php>.
  This collection catalogues life on Earth, focusing on the ancestor/descendant relationships that connect all organisms, past and present.

Suggestion for Assessment

Use the Thumbs strategy—thumbs up (I get it), thumbs down (I don't get it), 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.

Building Vocabulary (U1)

Introduce new vocabulary to students as required. Students benefit from assistance with vocabulary before they start to read science texts. The use of a variety of strategies and think-sheet frames (e.g., Word Cycle, Three-Point Approach) can aid students in developing both conceptual and contextual knowledge of the vocabulary of genetics. Refer to *SYSTH* (Chapter 10) for more information on building a scientific vocabulary and for examples of think-sheet frames.

Suggestion for Assessment

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

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-G1: Collaborate with others to achieve group goals and responsibilities. (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)

Understanding Domains and Kingdoms—Hierarchy Concept Map (U2, G1)

Students work in small groups to create Hierarchy Concept Maps summarizing the characteristics of the domains of life. When provided with the characteristics, students should be able to identify the domain to which an organism belongs.

Students then add the kingdoms of the Eukarya domain to the concept map and summarize the characteristics of each kingdom. When provided with the characteristics, students should be able to identify the kingdom to which an organism belongs (e.g., multicellular, heterotroph, cell walls made of chitin = fungi). Refer to *SYSTH* (pp. 11.16–11.17) for more information on Hierarchy Concept Maps.

Suggestion for Assessment

Assess students' Hierarchy Concept Maps for conceptual understanding, and provide descriptive feedback as to how the concept maps could be improved.

How Have New Technologies Changed Classification?—Demonstrating Understanding (U1, I4, N1)

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

- How have new technologies, such as DNA analysis and biochemical tests, changed the way organisms are classified?

Give students five minutes to respond in their notebooks.

DOMAINS OF LIFE

SPECIFIC LEARNING OUTCOMES

B12-4-05: Compare the characteristics of the domains of life. (GLOs: D1, E1)

Include: Archaea (Archaebacteria), Bacteria (Eubacteria), and Eukarya

B12-4-06: Compare the characteristics of the kingdoms in the Eukarya domain. (GLOs: D1, E1)

Include: cell structure, major mode of nutrition, cell number, and motility

Suggestion for Assessment

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

- DNA analysis can determine the relatedness of two species. The more similar the DNA sequences are, the more closely related the organisms are.
- DNA analysis can determine how long ago species began to diverge, using accumulated differences in DNA (molecular clocks).
- Biochemical tests determine the presence of specific molecules in cells. The more similar the specific molecules are, the more closely related the organisms are.
- DNA analysis and biochemical tests determined the Archaea were distinct from other bacteria with which they had previously been grouped. This led to the three-domain classification system.

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-G1: Collaborate with others to achieve group goals and responsibilities. (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

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

SLO: B12-4-07

SUGGESTIONS FOR INSTRUCTION

ENTRY-LEVEL KNOWLEDGE

In Grade 6 Science, students described the two main groups in the animal kingdom, vertebrates and invertebrates, and provided examples of representative organisms. Students also classified vertebrates as fishes, amphibians, reptiles, birds, and mammals, and provided examples to illustrate the diversity within each group.

TEACHER NOTE

Traditional Linnaean classification separated the extant terrestrial vertebrates into four classes: amphibians, reptiles, birds, and mammals. Three major classes of fish were recognized:

- Agnatha (jawless fishes such as lampreys)
- Chondrichthyes (cartilaginous fishes such as sharks and rays)
- Osteichthyes (bony fishes such as salmon and guppies)

Cladistics takes a different approach that is subject to ongoing debate. Some of the information presented in textbooks is in conflict with the more recent revisions to the tree of life. Consult journals and reputable Internet sites for current information.

A *cladogram* is a visual reconstruction of the evolutionary history of a group of organisms resulting from cladistic analysis. Cladograms appear as branching diagrams based on a sequenced pattern of ancestral (primitive) and derived (advanced) traits. Derived traits distinguish members of one evolutionary branch from another. All taxa are found at the endpoints of the cladogram. Note that some fan-like or tree-like diagrams showing evolutionary relationships are not cladograms, because they show ancestral species located closer to the base/trunk, and present-day species located at the ends of the blades/branches.

Phylogenetic trees and cladograms are dynamic (i.e., they are constantly being revised), based on the biological data used, new mathematical and computational ideas, and current and emerging knowledge.

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

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

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-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-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)

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)

ACTIVATE

What's a Fishapod?

Introduce students to *Tiktaalik roseae*, a 375-million-year-old fossil discovered on Ellesmere Island, Nunavut, in 2004. *Tiktaalik* is a transitional species, as it shares characteristics of ancient fish and early tetrapods (hence the term *fishapod*). After analyzing the fossil, the research team asked a Nunavut council of Elders to offer suggestions for a name for the species. They suggested *Tiktaalik*, which is Inuktitut for large freshwater fish.

Resource Link

- The University of Chicago. *Tiktaalik roseae*. <http://tiktaalik.uchicago.edu/>. Visit this website for information on the search for and discovery of *Tiktaalik*, including video clips, articles, and teaching tools.

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

ACQUIRE/APPLY

Interpreting Cladograms (U2, S1, I1)

Provide students with a cladogram and have them trace the evolutionary history of a group of organisms (e.g., phylogeny of modern birds from therapod dinosaurs, hominid evolution), identifying the derived traits.

Suggestion for Assessment

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

Dissection (P1, S1, S2, S3, S5)

Use a series of dissections or equivalent exercises with dissection software to examine the anatomy and physiology of representative vertebrates and/or invertebrates. Compare adaptations of each group for performing life functions. For example, compare circulation and respiration in earthworms, grasshoppers, squid, and sharks. Note that DNA analysis has replaced comparative anatomy in determining relationships among living things.

Students often find the odour of specimens preserved in formalin/formaldehyde offensive. To reduce the odour, soak the specimens overnight in fresh water. By changing the water a few times, the smell will be minimized.

Suggestion for Assessment

Assess students' lab skills during the investigation using a lab skills checklist. Lab reports can be assessed as well. See Appendix 1.4A: Lab Skills Checklist—General Skills (BLM) and Appendix 1.4B: Lab Skills Checklist—Thinking Skills (BLM). For various ways of writing a laboratory report, refer to *SYSTH* (pp. 11.26–11.29 and 14.11–14.12).

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

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

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-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-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)1

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)

Investigating an Evolutionary Trend—Research and Presentation/ Culminating Task (U2, P1, S1, I1, I3, I4, N1)

Students research an evolutionary trend in a group of organisms and present their findings to the class. Possible topics include the following:

- hominid evolution
- vascularization in plants
- cephalization in invertebrates
- evolution of flight in birds
- changes in the alternation of generations in plants
- development of the digestive tract in animals
- changes in vertebrate respiration (adaptations to life on land)

An investigation of this sort can be used as a culminating task for the unit, bringing together a number of knowledge and skills and attitudes learning outcomes.

INVESTIGATING EVOLUTIONARY TRENDS

SPECIFIC LEARNING OUTCOME

B12-4-07: Investigate an evolutionary trend in a group of organisms. (GLOs: C2, C5, C6, E1)

Examples: hominid evolution, vascularization in plants, animal adaptations for life on land . . .

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.

Suggestions for Assessment

Students prepare and present their research outlining an evolutionary trend in a group of organisms. Research findings can be presented in a variety of formats:

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

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).

Create an assessment rubric for the report/presentation 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. Assessment criteria should include both content and presentation components. Alternatively, provide students with exemplars of strong and weak reports, and have them work in groups to identify possible assessment criteria and define levels of performance. The exemplars can be anonymous samples of student work done in previous years.

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

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

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-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-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)

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)

Last Word (U2)

At the end of the unit, students repeat the process outlined in First Word (see learning outcomes B12-4-01 and B12-4-02), using a new page in their notebooks to create Last Word acrostics.

Suggestion for Assessment

After students have completed their Last Word acrostics, refer them to their First Word acrostics. Students compare the two pages and self-assess their work, reflecting on how their conceptual understanding has progressed. The information from Last Word can be used to identify whether further lessons are required (formative assessment).

NOTES

UNIT 4:
ORGANIZING BIODIVERSITY

APPENDICES

Appendix 4.1: Definition of a Species (Teacher Background)

The species is the only taxonomic category with a clear biological identity. 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. In other words, species are defined by their genetic integrity because they share DNA with each other and not with other species.

There are difficulties with the definition of species. For example, a mule is the offspring of two distinct species, a donkey and a horse. How, then, does one classify a mule? Because mules are sterile and cannot reproduce, they are considered to be hybrids, not a species. Other examples of hybrids are Galapagos finches that interbreed, but whose offspring are sterile.

Some species show such a wide range of phenotypic variations that it is not initially obvious they all share a common gene pool. Dogs (*Canis familiaris*) come in a great variety of shapes and sizes. It may be difficult to believe that the Chihuahua and Great Dane are members of the same species. The breeding plumage of male birds often differs significantly from that of females and juveniles within a species.

Occasionally, non-interbreeding subpopulations exist within a species. Several subspecies of deer mice (*Peromyscus maniculatus*) are present in North America. Deer mice are best known as carriers of hantavirus. One subspecies, *Peromyscus maniculatus bairdii*, prefers open areas such as plowed or cultivated fields and grasslands, while *Peromyscus maniculatus gracilis* is found in forests. In addition to occupying different habitats, the mice differ in appearance. While the two subspecies may occupy the same area, they do not interbreed. They will, however, interbreed with other subspecies of deer mice.

Appendix 4.2A: Peer Assessment (Teacher Background)

Peer assessment involves students in assessing each other's work. Along with self-assessment, peer assessment is a component of assessment *as* learning, emphasizing student growth and self-understanding (metacognition). By engaging students as partners in the formative assessment process, peer assessment provides students the opportunity to practise and receive feedback without being graded on their work. Students gain a sense of ownership in the assessment process, thereby improving their motivation for learning.

When students discuss each other's work and make suggestions for improvement, they think analytically. This analytical thinking can be extended to their thinking about their own work, promoting self-reflection and self-assessment. Students develop the skills and habits of mind to take increasing responsibility for their own learning, and develop as independent, self-directed learners. They learn to recognize the characteristics of quality work.

In order for peer assessment to be used effectively in the classroom, certain prerequisites must be met.

1. Students must have a strong grasp of what they are to look for in their peer's work. Exemplars of strong and weak work can help students understand the assessment criteria and how to perform well. Engaging students in developing the assessment criteria also serves to extend their knowledge of the expectations concerning their work.

2. Peer assessment must be structured so that students understand they are to rate the work, not the student. By modelling effective descriptive feedback, teachers can help students formulate constructive feedback that is not judgmental. Students should be encouraged to be consistent, realistic, positive, and reflective when providing feedback to one another.

3. The learning environment in the classroom must be supportive. Students must feel comfortable and trust one another in order to provide honest and constructive feedback. By treating assessment as part of learning, students will come to view mistakes as opportunities for learning, rather than failures.

Peer assessment is a valuable means of formative assessment, as it allows students to ask each other questions they may be reluctant to ask their teacher, and explain things to each other using familiar language. Students see each other as resources for understanding when they have the opportunity to discuss new information, challenge ideas, and share explanations with each other. By supporting and scaffolding each other's learning, students can achieve beyond what they can learn on their own.

Appendix 4.2B: Guidelines for Peer Assessment (BLM)

When assessing the work of a peer, consider the following guidelines:

1. Focus on the work and process.
   - Give process-focused comments that suggest how to move the work closer to the target (e.g., Have you checked the Citation and Documentation handout for examples of the format to use for your reference page?).
   - General praise (e.g., Good work!) or personal comments (e.g., I like it!) are not helpful.
2. Provide non-judgmental, descriptive feedback.
   - Always talk about the work, not the person (e.g., I noticed that some boxes in the Concept Overview Frame have not been completed, NOT You didn't finish the Concept Overview Frame.).
   - Don't make judgments or evaluative statements about the work (e.g., This work is a failure.).
3. Be positive and make specific suggestions.
   - Describe how the strengths in a student's work match the criteria for good work (e.g., The conclusion in this lab report is stated clearly).
   - Describe what is missing or could be done better. Use a tone that shows you are making helpful suggestions (e.g., I'm not sure I understand your reasoning in this genetics problem. Could you explain it in another way?).

Examples of Feedback Prompts

- I am confused about the answer to this question. Can you explain your reasoning another way?
- Can you describe the strategy that you used to solve this problem?
- Have you checked your calculations in this question? Does $(0.2)^2 = 0.4$?
- I noticed you left some questions unanswered in the case study. Is there anything I can help you with?
- Your lab report is clear and organized. Have you checked your spelling and grammar?
- Your decision regarding the ethical dilemma is clear. What were the criteria you used to make this decision?
- Could you explain to me how you came to this conclusion based on the data you collected?

Appendix 4.3: The Changing Nature of Classification (Teacher Background)

The dynamic nature of classification is an excellent example of how the use of new and improved technologies have led to changes in the entire system of classification.

- Aristotle (384–322 BCE) created the first widely used classification system by dividing all organisms into two groups: plants and animals.
- Carolus Linnaeus (1707–1778) developed the hierarchical categorization system (kingdom, phylum, class, order, family, genus, species), and grouped organisms based on their resemblance to other life forms. The binomial nomenclature system developed by Linnaeus is still in use today.
- Improvements in light microscopes led to the discovery of a great number of single-celled organisms. Ernst Haeckel suggested in 1866 that these organisms be placed in a separate kingdom called *Protista*.
- The invention of the electron microscope and advances in biochemistry in the mid-1900s led to the discovery of the two different types of cells: the prokaryotes (bacteria) and the eukaryotes (plants, animals, fungi, and protists).
- Robert Whittaker proposed the five-kingdom system in 1959. Plants, animals, fungi, bacteria, and protists were placed in separate kingdoms: Plantae, Animalia, Fungi, Monera, and Protista.
- Carl Woese's analysis of the base sequence of ribosomal RNA in various bacteria in the 1970s led Woese to suggest that bacteria be subdivided into two distinct groups: the Eubacteria and Archaebacteria.
- Based on Woese's research, a six-kingdom system was suggested. The plant, animal, fungi, and protist kingdoms remained, while the bacteria kingdom was separated into the Eubacteria and Archaebacteria kingdoms. In 1990, Woese proposed the three-domain scheme of classification consisting of the following domains:
  - Eukarya (all eukaryotes including animals, plants, fungi, and protists)
  - Bacteria ("true" bacteria such as *E. coli, Lactobacillus bulgaris*, and *Cyanobacteria*)
  - Archaea (organisms that live in extreme environments such as high temperature or extreme salinity, or produce methane gas)

Appendix 4.4: Species and Systematics—Demonstration (Teacher Background)

Bring varieties of *Brassica oleracea* and other vegetables to the class, such as the following:

- cabbage (*Brassica oleracea capitata*)
- kale (*Brassica oleracea acephala*)
- broccoli, cauliflower, broccoflower (*Brassica oleracea botrytis*)
- Brussels sprouts (*Brassica oleracea gemmifera*)
- kohlrabi (*Brassica oleracea caulo-rapa*)
- turnip (*Brassica rapa*)
- bok choy (*Brassica chinensis*)
- iceberg lettuce (*Lactuca sativa*)

Show students the vegetables and ask them to categorize the vegetables into genus and species. Students will likely group species according to look-alikes (e.g., iceberg lettuce and cabbage).

When students have made their arrangement, show them the actual groupings and their genus and species names. Note that obvious morphological traits are not always important in defining species. In this case, the detail of the flowers present is used to define the *Brassica* genus, and the arrangement of stalks defines the *Brassica* species.

The varieties of *Brassica oleracea* are all artificially selected and derived from the wild type that grows on the sea cliffs of Europe. The number of *Brassica oleracea* varieties is a representation of the genetic variation in a species. Artificial selection can be demonstrated with broccoli, cauliflower, and broccoflower (*Brassica oleracea botrytis*), which have been bred for selected traits. Remind students of the role that artificially bred plants and animals played in the development of Charles Darwin's ideas on natural selection.

Discuss the system of binomial nomenclature for naming species, developed by Carl Linnaeus and still in use today. These samples effectively reinforce the idea that the scientific names do mean something (if you know Latin and Greek).

- *brassica* = cabbage
- *acephala* = no head
- *capitata* = head botrytis = bunch of grapes
- *oler* = greens
- *caulo* = turnip
- *rapa* = stem
- *gemmifera* = bud-bearing
- *chinensis* = Chinese
- *lactuca* = lettuce

Appendix 4.5: Categorical Reasoning in Biology (BLM)

Introduction

Something that is true about a group or a category will be true for every member of that group or category. For example, you know that all birds are vertebrates. You also know that a robin is a type of bird. Therefore, you could reason that a robin is a vertebrate.

This type of reasoning is known as *categorical reasoning*. Categorical logic is the basis for classification systems. It examines relationships according to groups or categories of things. The argument can be set up formally as follows:

Premise: All birds are vertebrates.

Given: A robin is a bird.

Conclusion: A robin is a vertebrate.

Questions

1. Using the example above as a model, construct a categorical argument to show that a Labrador retriever is a mammal.
2. Explain the thought processes you used in answering question 1.
3. Construct a categorical argument to show that a pine tree is a plant.
4. Is the categorical logic below correct? Explain your thinking.

   Premise: All horses are herbivores.

   Given: Organism X is a herbivore.

   Conclusion: Organism X is a horse.

Appendix 4.6: The Three Domains of Life (Teacher Background)

In 1990, Carl Woese proposed the following three-domain scheme of classification:

- **Domain Eukaraya** (all eukaryotes, including animals, plants, fungi, and protists). Members of this domain are composed of eukaryotic cells that contain nuclei and membrane-enclosed organelles such as mitochondria and chloroplasts.
- **Domain Bacteria/Eubacteria** ("true" bacteria such as *Escherichia coli, Lactobacillus bulgaris*, and *Nostoc* spp.). Members of this domain are composed of prokaryotic cells, but they are biochemically and genetically distinct from the Archaea in that their cell walls contain the protein peptidoglycan.
- **Domain Archaea** (organisms such as *Acidianus* spp., *Halobacterium* spp., and *Methanobacterium* spp. that live in extreme environments). Members of this domain are composed of prokaryotic cells, but they are biochemically and genetically distinct from the Bacteria in that their RNA contains distinct sequences. In fact, Archaea are probably more closely related to humans than they are to Bacteria.

Current research uses molecular genetics and DNA/RNA sequencing to determine evolutionary relationships. Rapid gains in knowledge are leading to a reclassification of organisms, particularly the Protista kingdom. This group contains a diverse group of single-celled organisms that do not fit in the Plantae, Animalia, or Fungi kingdoms. This group is organized into several distinct kingdoms such as Chromista (e.g., diatoms, kelp), Rhodophyta (e.g., red algae), and Myxomycophyta (e.g., slime moulds).

New names are coming into to use for kingdoms Animalia and Plantae. Some sources are using Metazoa (animals) and Chlorobionta (plants) to reflect the changes in classification based on phylogenetics.