Manitoba

Education, Citizenship and Youth

Grade 12 BIOLOGY
A Foundation for Implementation
Part 2 - Biodiversity
Unit 4 – Organizing Biodiversity

DRAFT / Unedited Version

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Unit 4 - ORGANIZING BIODIVERSITY

S4B-4-01 Define the concept of biodiversity in terms of ecosystem, species and genetic diversity.

S4B-4-02 Discuss the difficulty in determining a definition of species. Examples: hybrids such as mules, phenotypic variations in a species, non-interbreeding sub-populations…

Entry-level Knowledge

In grade 6 Science, students develop an appreciation for the diversity of living things. They provide examples of a variety of animals (vertebrate and invertebrate) to illustrate their diversity, and observe and describe the diversity of living things within the local environment.
In grade 7 Science, students investigate the complex interactions between organisms and their environment. They define ecosystem and provide examples of a range of ecosystems.
In Senior 2 Science, students examine the relationships present in ecosystems to investigate issues of sustainability, and explore the concepts and implications of species biodiversity. They observe and document a range of organisms that illustrate the biodiversity of a local or regional ecosystem, and explain how the biodiversity of an ecosystem contributes to its sustainability.

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 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 therefore 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. There are several subspecies of deer mice (*Peromyscus maniculatus)* present in North America. Deer mice are best known as carriers of the Hanta virus. 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.

Teacher Notes
Students will be familiar with the term species, but may not have previously explored the topic in depth.

Suggestions for Instruction

Activate

Brainstorm

Divide the class into small groups of 2-4 students and provide each group with a small package of Post-it-notes. Give the students 2 minutes to brainstorm and record the specific names of as many types of organisms as possible, writing the name of one organism per Post-it-note. Ask students to include a variety of types of organisms (plant, animal…) from different ecosystems. If the students do not know the name of an organism, they can describe it.

While students are brainstorming, write several types of ecosystem on the board. Ask students to then group the organisms according to the ecosystems in which they would be found (e.g. lake, urban, boreal forest…) and post their organisms in the appropriate ecosystem.
Pose questions such as:

- Are there 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? (i.e. 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

Direct Instruction

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.

Discuss with students the difficulties in determining the definition of a species (i.e. hybrids, phenotypic variation within a species, non-interbreeding subpopulations). Examples can be found in Teacher Background above.

Class Discussion
Provide students with pictures of the Eastern Meadowlark and the Western Meadowlark. Ask them if 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.

Case Study
At what point in evolutionary development does a group of individuals become two distinct species? This case addresses this question by asking students to decide whether apple maggot flies are distinct as a species from hawthorn maggot flies. In making their decision, students examine the different models of speciation and consider the primary forces that effect evolutionary change. See Appendix 1: Case Study - As the Worm Turns: Speciation and the Apple Maggot Fly (BLM).

Suggestions for Assessment
Visual Presentation
Students or student groups each select a species that shows obvious phenotypic variation. Students discuss and present to the class the reasons why the organisms are considered to be members of the same species. Power point or digital technology can be used.

Assess student presentations for logic and accuracy. The response should contain information such as:

- Members of the same species have genetic integrity
- Members of the same species share DNA with each other and not other species
- Because of this, member of the same species share a common gene pool. This makes them a distinct biological unit.

S4B-4-03 Describe the dynamic nature of classification.
Include: different systems, current debates.

Entry-level Knowledge
In grade 6 Science, students are introduced to classification systems, and construct and use their own as well as those developed by others. In doing so,

students recognize the advantages and disadvantages of classification systems in organizing information.

Teacher Background

Systematics is the branch of biology that deals with classifying living things, both current and prehistoric. There are three components:

- Taxonomy –describing and naming new taxonomic groups
- Classification – organizing information about organisms by arranging them into a hierarchical system
- Phylogenetics – determining the evolutionary history and relationships among the various forms of life through time. Relationships among organisms are expressed through diagrams known as cladograms.

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

- Aristotle (384-322 BCE) created the first widely used classifications 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 1900's led to the discovery of the two different types of cells; the prokaryotes (bacteria) and the eukaryotes(plants, animals, fungi, protists).
- Robert Whittaker proposed the five kingdom system in 1959. Plants, animals, fungi, bacteria and protists were placed in separate kingdoms.
- Analysis of the base sequence of ribosomal RNA in various bacteria by Carl Woese in the 1970's led him to suggest that bacteria be subdivided 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 Kingdom Monera (bacteria) was separated into the Eubacteria and Archaebacteria kingdoms.
- In 1990, Woese proposed the three domain scheme of classification consisting of Domain Eukaraya (all eukaryotes including animals, plants, fungi and protists), Domain Bacteria ("true" bacteria such as *E. coli, Lactobacillus bulgaris,* and *Cyanobacteria*), and Domain Archaea (organisms that live in extreme environments such as high temperature or extreme salinity, or produce methane gas)

Teacher Notes
A discussion of classification can be enhanced with the use concrete examples of organisms (e.g. preserved animal specimens, plant material…).

New information obtained from DNA and RNA sequencing has lead to sweeping changes in classification since 1990. Even the most recent versions of high school biology textbooks can be out of date. Be sure to consult journals and reputable Internet sites for current information.

Students will be most familiar with traditional classification (known as the phenetic method) of organisms. This method classifies organisms using morphological similarities and relatedness, but fails to fully reconstruct evolutionary relationships among organisms.

Cladistics was developed by the German biologist Willi Hennig. 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.

The phenetic and cladistic approaches often do result in the same classification of organisms. However, there are some differences that can result in confusion for students. See Teacher Background in S4B-4-07 for a discussion on the changing nature of vertebrate classification.

Suggestions for Instruction

Activate

Opening Question

Pose the following to students:
Think about your home, school and neighbourhood. Can you think of any examples of classification systems in use?
Examples may include:

- Library (Dewey decimal system)
- Grocery store (what items are found in which isles)
- DVD rental shop (how the movies organized)
- Students in school (by grade)
- Clothing at home (e.g. sock drawer, shirt drawer…)

Acquire/Apply

Demonstration

This demonstration uses a variety of vegetables to introduce and follow up a discussion of species and systematics. See Appendix 2 for more information.

Critical Thinking

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 3: Categorical Reasoning in Biology (BLM) for the student activity.

Suggestions for Assessment

Investigation

There are a variety of activities available in lab manuals, textbooks and on the Internet for developing and using classification systems and dichotomous keys. Assess student lab reports for accuracy in the responses to questions. Lab skills can also be assessed using a checklist.

Resources

The Palaeos website (www.palaeos.com) provides information on phylogeny, paleontology, evolution, and earth history.

The University of California, Berkeley, Museum of Paleontology website contains a Phylogeny wing (www.ucmp.berkeley.edu/exhibit/phylogeny.html) that explores the ancestor/descendant relationships which connect all organisms, past and present.

S4B-4-04 Describe types of evidence used to classify organisms and determine evolutionary relationships.
Examples: fossil record, DNA analysis, biochemistry, embryology, morphology…

Entry-level Knowledge

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

Teacher Background

Traditional phenetic classification was based on similarities in morphology among species. It relied on the fossil record (paleontology), homologies and embryology to determine relationships between organisms.

Cladistics is a method that 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 and RNA sequencing is an important technique for determining the phylogenetic relationships.

Teacher Notes

Be sure to differentiate between phylogenetic trees and cladograms, as both are in use today. A cladogram is a visual reconstruction of the evolutionary history of a group of organisms. 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. .

A phylogenetic tree appears as a fan-like or tree-like diagram, with the base/trunk representing the origin of life and the blades/branches representing the various different groups of organisms. Ancestral species are located closest to the base/trunk, and present day species are located at the ends of the blades/branches.

Suggestions for Instruction

Activate

Field Trip

The Manitoba Museum's Earth History Gallery traces Manitoba's geologic past and has fossils of various life forms such as trilobites and a plesiosaur.
The Morden Museum has exhibits of Cretaceous period marine fossils including mosasaurs, squid, sharks and seabirds. A visit to a local dig can be arranged

Acquire/Apply

Jigsaw

Assign student groups a particular type of evidence used in the science of classification (e.g. fossil dating, DNA…). Each group then investigates their technology or tool. The groups then prepare one-page summaries outlining how their technology or tool is used in classifying organisms and determining phylogenetic relationships.

Jigsaw the groups, and arrange the students so that each new group contains one expert from each of the previous groups. Each expert then shares his/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.

Web Activity
The Riddle of the Bones is a web activity in which students use fossil evidence to determine how one of our early ancestors appeared. The activity is part of the PBS Evolution website and is located at www.pbs.org/wgbh/evolution/humans/riddle/.

Web Activity
The interactive module "What Did *T.rex* Taste Like"' is an introduction to cladistics and involves students in posing hypotheses about past life based upon evolutionary history. The module is part of the University of California Museum of Paleontology website and is located at www.ucmp.berkeley.edu/education/explorations/tours/Trex/index.html.

Suggestions for Assessment

Group Work
Students use a rating scale to assess their collaborative group work processes. See Appendix 4: Assessment – Collaborative Process.

Investigation
There are a variety of activities available in lab manuals, textbooks and on the Internet for examining evidence used to classify organisms and determine evolutionary relationships.
Assess student lab reports for accuracy in the responses to questions. Lab skills can also be assessed using a checklist.

Exit Slip
While pigeons are often mocked as "rats with wings", pigeons (and all birds) are more closely related to carnivorous dinosaurs such as *Tyrannosaurus* and *Velociraptor* 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?
Student responses can include:

- Fossils (e.g. *Archeopteryx)*
- Dating of fossils (e.g. radio-isotopes such as carbon-14)
- Similarities in structure (e.g. presence of wishbone, structure of hip bones)
- Fossil record (showing changes over time)
- DNA analysis (e.g. avian DNA is more similar to crocodilian DNA than it is to mammalian DNA)

Resources
The University of California, Berkeley, Museum of Paleontology website contains a Geology wing (www.ucmp.berkeley.edu/exhibit/geology.html) that explores the geologic time scale, the fossil record, stratigraphy and plate tectonics.

The University of California, Berkeley, Museum of Paleontology website contains the Journey into Phylogenetic Systematics (http://www.ucmp.berkeley.edu/clad/clad4.html) that explains the science of cladistics.

The PBS Nova episode "The Missing Link" (Feb. 26, 2002) documents the search for the tetrapod ancestral to all four-limbed animals. Visit the website http://www.pbs.org/wgbh/nova/link.

S4B-4-05 Compare the characteristics of the domains.
Include: Archaea (Archaebacteria), Bacteria (Eubacteria), Eukarya.

S4B-4-06 Compare the characteristics of the kingdoms in the Eukarya domain.
Include: cell structure, major mode of nutrition, cell number, motility.

Entry-level Knowledge
In grade 6 science, students identify the five kingdoms (i.e. monerans, protists, fungi, plants, animals) commonly used for the classification of living things and provide examples of organisms from each kingdom to illustrate the diversity of living things.

Teacher Background
In 1990, Carl Woese proposed the three domain scheme of classification consisting of:

- 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 ("true" bacteria such as *E. coli, Lactobacillus bulgaris,* and *Cyanobacteria*). Members of this domain are composed of prokaryotic cells, but they are biochemically and genetically distinct from the Archaeans in that their cell walls contain the protein peptidoglycam.
- Domain Archaea (organisms that live in extreme environments such as *Acidianus, Thermodiscus,* and *Methanobacteriales*). 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, Archaeans are probably more closely related to humans than they are to bacteria.

Current research is using molecular genetics and DNA/RNA sequencing to determine evolutionary relationships. Rapid gains in knowledge are leading to a reclassification of organisms. Recently, the new kingdom Chromista has been proposed to include diatoms, kelps and downy mildew. These organisms are distinct from plants as they contain chlorophyll c and do not store their energy as starch.

There are on-going discussions about the kingdom Protista. It contains a diverse group of single-celled organisms that do not fit in the other kingdoms. Many question whether this group should be divided into three or more distinct kingdoms. 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.

Teacher Notes
Be aware of the extensive changes in classification since 1990. Even the most recent versions of high school biology textbooks can be out of date. Be sure to consult journals and reputable Internet sites for current information.

The phylogenetic relationships among organisms are currently subject to intense debate. This can lead to great confusion for students when consulting 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.

Suggestions for Instruction

Activate

Matching
Provide students with the names of the Eukarya kingdoms and a picture of a representative organism from each kingdom. Ask students to match the organism with the appropriate kingdom. Students should be able to explain their reasoning for making their matches.

Acquire/Apply

Direct Instruction
Use a diagram to illustrate and describe the relationship among three domains of living things. Explain how genetic and biochemical analyses changed biological classification. Discuss with students the characteristics of each domain and provide examples of representative organisms.

Concept Map
Students create a chart comparing the characteristics of the domain. When provided with the characteristics, students should be able to identify the domain to which an organism belongs.

Students then add the Eurkarya kingdoms to the chart in order to compare the characteristics of the Eukarya kingdoms. 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).

Suggestions for Assessment

Exit Slip

Pose the following:
How have new technologies, such as DNA analysis and biochemical tests, changed the way we classify organisms?

Examine student responses for logic and accuracy. The response should contain information such as:

- DNA analysis can determine the relatedness of two species. The more similar the DNA sequences, 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, the more closely related the organisms are.
- DNA analysis and biochemical tests determined the Archaens were distinct from other bacteria with which they had been previously grouped. This led to the three domain classification system.

Resources

The Tree of Life website (www.tolweb.org) contains information about the diversity of organisms on Earth, their evolutionary history, and characteristics.

The University of California, Berkeley, Museum of Paleontology website contains a Phylogeny wing (www.ucmp.berkeley.edu/exhibit/phylogeny.html) that explores the ancestor/descendant relationships which connect all organisms, past and present.

S4B-4-07 Investigate an evolutionary trend in a group of organisms. Examples: hominid evolution, vascularization in plants, animal adaptations for life on land…

Entry-level Knowledge

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

Teacher Background

Traditional phenetic classification separated the extant terrestrial vertebrates into four classes: amphibians, reptiles, birds and mammals. Three major classes of fish were recognized. These were the agnathans (jawless fishes such as lampreys), chondrichthyes (cartilaginous fishes such as sharks and rays) and osteichthyes (bony fishes such as salmon and guppies).

Cladistics takes a different approach that is subject to on-going debate. The terrestrial vertebrates are grouped into the taxon Tetrapoda. This taxon contains the groups Amphibia and Amniota. The Amphibians consist of animals such as frogs, salamanders, and toads. The Amniotes include the anapsids (turtles), the diapsids (snakes, crocodiles, dinosaurs, birds) and the synapsids (mammals).

Because lobe-fin fishes are closely related to amphibians, they are not grouped with the bony fishes (Osteichthyes). Instead they are grouped with the Sacopterygii (aka Crossopterygii), the larger set to which the Tetrapods also belong.

Teacher Notes

Be aware of the extensive changes in classification since 1990. Even the most recent versions of high school biology textbooks can be out of date. Be sure to consult journals and reputable Internet sites for current information.

The phylogenetic relationships among major animal groups are currently subject to intense debate. This can lead to great confusion for students when consulting various sources of information.

Suggestions for Instruction

Activate

The evolutionary history of some organisms is well represented in the fossil record. Trace the evolutionary history of the camel, elephant or horse with the class.

Acquire/Apply

Cladogram

Provide students with a cladogram and have them describe the evolutionary history of a group of organisms (e.g. phylogeny of modern birds from therapod dinosaurs, homind evolution), identifying the derived traits. Assess student analyses for accuracy in identifying derived traits.

Dissection
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 of the phyla for performing life functions. For example, compare circulation and respiration in earthworms, grasshoppers, squid and sharks.

Investigation
Provide students with the following list of plant groupings:
- Hepaticophyta (liverworts)
- Bryotphyta (mosses)
- Pterophyta (ferns)
- Coniferophyta (conifers)
- Anthophyta (flowering plants)

Students research the characteristics of the groups, identifying the trends in adaptations by plants to life on land (e.g. vascularization, development of roots, stems and leaves, reducing water loss, reproductive strategies…).
Students then construct a phylogenetic tree diagram showing the evolutionary relationships among plants. Phylogenetic trees can be assessed for accuracy.

Investigation
Provide students with the following list of vertebrate classes (based on phenetic classification):
- Agnatha (jawless fishes)
- Chondrichthyes (cartilaginous fishes)
- Osteichthyes (bony fishes)
- Amphibia (amphibians)
- Reptilia (reptiles)
- Mammalia (mammals)
- Aves (birds)

Students research the characteristics of each class, and then construct a phylogenetic tree diagram showing the evolutionary relationships of the vertebrates. Phylogenetic trees can be assessed for accuracy.

Suggestions for Assessment
Poster
Break class into small groups and assign each group a different animal phylum. (The nine major animal phyla in phenetic classification are Porifera, Cnidaria, Platyhelminthes, Nematoda, Mollusca, Annelida, Arthropoda, Echinodermata, Chordata.) Students then research their assigned phylum, making note of representative organisms, phylum characteristics, and their fit in the world (e.g. parasites, coral reef builders, food source for humans, pollinators…).

When the research is complete, each group creates a poster to display the information. The poster should contain:

- the name of the phylum
- the common name of the phylum (if any)
- examples of at least two representative organisms, including names and pictures
- phylum characteristics
- the phylum's fit in the world

Display the posters around the room. Conduct a gallery walk, allowing students to view the posters and to make notes on each phylum. Following the gallery walk, lead the class in a discussion of the evolutionary trends in the animal kingdom (e.g. cephalization, body symmetry, cellular organization, segmentation, body cavities…).

The posters can be teacher- or peer-assessed using the Performance Assessment: Poster Rating Scale. See Appendix 5 for the Black Line Master.

Resources

The University of California, Berkeley, Museum of Paleontology website contains a Vertebrate Flight Exhibit (www.ucmp.berkeley.edu/vertebrates/flight/enter.html) that explores the evolution of flight in vertebrates.

Appendix

Appendix 1a: Case Study - As the Worm Turns: Speciation and the Apple Maggot Fly

Introduction

Hawthorn trees grow throughout North America and produce a small fruit, which is eaten by a small fly larva. In 1864, apple growers in New York State discovered an unknown maggot had stared feeding on apples. Through the years, hawthorn and apple maggot flies have become progressively more distinct.

Information taken from the original scientific literature is presented below. Consider and evaluate the evidence in order to answer the following two questions:

1. Do hawthorn maggot flies and apple maggot flies belong to the same species?
2. If not, and if apple maggot flies belong to their own species, what would be a biologically reasonable scenario for how speciation occurred?

Facts about Hawthorn and Apple Maggot Flies

- The apple maggot fly and the hawthorn maggot fly are both assigned to the same species (*Rhagoletis pomonella*) (Bush, 1969).
  - Hawthorn maggot flies and apple maggot flies are physically indistinguishable.
  - There is no geographic isolation or physical separation between adult maggot flies.
- *R. pononella* is native to eastern North America and it originally bred in the fruit of hawthorn trees (Reissig, 1991).
- *R. pomonella* belongs to a set of four closely related fly species that cannot be physically distinguished. (Berlocher and Bush, 1982).

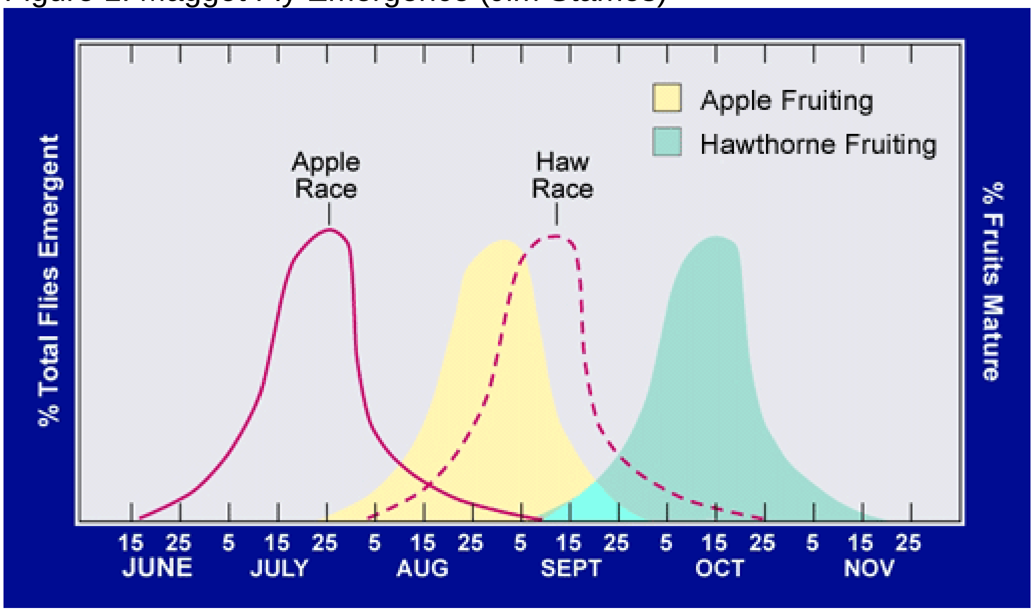
Facts about Hawthorn and Apple Trees

- Both the hawthorn and the apple are woody plants that belong to the Rose family (Newcomb, 1977).
  - Hawthorns are group of about 50 species of trees and shrubs native to North America. They are assigned to the genus *Crataegus.*
  - Early European settlers introduced apples to North America. Apples are assigned to the genus *Malus.*
- The apple is the most widely grown fruit in North America.
- The maggot fly is a major fruit pest in eastern Canada and northeastern United States. Thorough control of the maggot fly is needed to produce high quality and marketable fruit (Reissig, 1991)

Facts about Maggot Fly Reproduction

- Maggot flies that reproduce on apples are known as the apple race, while maggot flies that reproduce on hawthorns are known as the haw race.
- Figure 1 is a general representation of the timing of fly emergence (solid and dashed lines) and fruit ripening (coloured filled-in curves).

Figure 1: Maggot Fly Emergence (Jim Stamos)



- Adult fruits emerge to reproduce before the fruits are mature.
  - The female fly lays fertilized eggs into the ripe fruit.
  - Maggots hatch from the eggs, eat fruit, grow and pupate (Reissig, 1991).
- Apple fruits ripen approximately 1 month earlier than hawthorn fruits, but there is overlap at the end of the end of the apple fruiting season and the beginning of the hawthorn fruiting season (Belocher and Feder, 2002).

Facts about Hawthorn and Apple Fruits

- The typical commercial apple has a diameter of 70 mm, while the typical wild hawthorn has a diameter of 12.5 mm.
- The larger fruits of apple trees provide 5.5 times more depth (based on diameter) to developing maggots than do hawthorn fruits.
  - Parasitoid wasps lay eggs into to maggot's body, with the wasp larvae ultimately killing the maggot.
  - Apple maggots are better able to escape parasitoid wasps by burrowing deeper into the fruit that the wasp can penetrate with its egg-layer (ovipositor)
  - Apple maggots bear 70% fewer parasitoid was eggs than do hawthorn maggots (Berlocher and Feder, 2002).

- The larger fruits of apple trees provide 220 times more food (based on volume) to the growing and developing maggot than the smaller fruits of hawthorns.
  - Apple maggot flies lay more eggs per fruit than do hawthorn maggot flies.
  - The nutritional quality of hawthorn fruit is indicated by the better survival of both types of maggots in hawthorn fruits; 52% of maggot fly eggs survived in hawthorn fruits and 27% of maggot fly eggs survived in apple fruits (Prokopy et al, 1988; Freeman and Herron, 1998).
  - Caterpillars and weevils may also feed on the lager apple, reducing the quantity of food available to apple maggots.

Evolutionary Outcomes in Apple Maggot Flies

- Fidelity to fruit type acts as a strong barrier to gene flow between the two types of maggot flies.
  - There is only a 4 – 6% hybridization rate between hawthorn maggot flies and apple maggot flies (Berlocher and Feder, 2002).
  - Hawthorn maggot flies strongly prefer to mate on and lay fertilized eggs into hawthorns.
  - Apple maggot flies strongly prefer to mate on and lay fertilized eggs into apples.
- Hawthorn and apple maggot flies are genetically distinguishable. They have recognizable genetic profiles (Berlocher and Feder, 2002).

Questions

In small groups, address the following and list the evidence used to make your decisions.

1. What species concept should be used in this case?
2. Are apple maggot flies distinct as a species from hawthorn maggot flies?
3. Propose a biologically reasonable scenario that explains how apple maggot flies evolved.
4. How did you weigh the different pieces of evidence to reach a conclusion to questions 2 &3? What evidence was most important? What evidence was least important?
5. What further information would you need to increase your confidence in the conclusions you reached?

Adapted from As the Worm Turns: Speciation and the Apple Maggot Fly, by Martin G. Kelly, Buffalo State College, National Center for Case Study Teaching in Science, University at Buffalo, State University of New York.

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Appendix 2: Species and Systematics - A Demonstration

Introduce and follow up your discussions for species and systematics with the following demonstration:

Bring in varieties of *Brassica oleracea* and other vegetables such as:
- Cabbage (*Brassica oleracea capitata)*
- Kale (*Brassica oleracea acephala)*
- Broccoli, cauliflower, broccoflower (*Brassica oleracea botrytis*)
- Brussel sprouts (*Brassica oleracea gemmifera*)
- Kohlrabi (*Brassica oleracea caulo-rapa)*
- Turnip (*Brassica rapa)*
- Bok choy (*Brassica chinensis*)
- Iceberg lettuce (*Lactuca sativa*)

Note: The varieties of *Brassica oleracea* are all artificially selected and derived from the wild-type that grows on the sea cliffs of Europe.

Show students the vegetables and ask them to categorize the vegetables into genus and species. Students will probably 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 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.

Discuss the scientific names. These samples are good for reinforcing the idea that the scientific names do mean something (if you know Latin and Greek).

Latin	Greek
brassic = cabbage	acephala = no head
capitata = head	botrytis = bunch of grapes
oler = greens	
caulo = turnip	
rapa = stem	
gemmifera = bud-bearing	
chinesis = Chinese	
lattuca = lettuce	

The number of *Brassica oleracea* varieties is an excellent 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 Darwin's ideas on natural selection.

(adapted from Fenster, E. and F. Rhodes (1997) *Biology Concepts & Connections Instructors Guide 2nd edition*. Benjamin/Cummings: Melno Park, CA.)

Appendix 3: 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 your thought processes as you answered question 1.

3. Construct a categorical argument to show that a pine tree is a plant.

4. What is wrong with the categorical argument below?
   Premise: All horses are herbivores.
   Given: Organism X is a herbivore.
   Conclusion: Organism X is a horse.

Appendix 4: Assessment – Collaborative Process (BLM)

Assess your collaborative processes using the following rating scale:

Rating Scale:

4 We were consistently effective in this area.
3 We were usually effective in this area and experienced few problems.
2 We were sometimes effective in this area. We experienced some problems, some of which we resolved.
1 We were note effective in this area. We experienced problems that we did not attempt to resolve.

Group Process Rating

- We were respectful of individual group members' approaches and strengths.
- We encouraged and supported each person in contributing to group research, discussion and decision-making.
- We questioned and challenged each other's ideas, but did not not make personal attacks.
- We shared work and responsibilities equitably.
- We dealt successfully with the problem of absent or disengaged members.
- We used our time productively.

Appendix 5: Performance Assessment - Poster Rating Scale (BLM)

Element	Rating			
1. The title of the poster is easily identifiable and includes the name of the phylum and common name (if any).	1	2	3	4
2. Pictures and/or drawings of at least two representative organisms and their names are present on the poster	1	2	3	4
3. Descriptions of phylum characteristics contain sufficient information.	1	2	3	4
4. Descriptions of the phylum's fit in the world contain sufficient information.	1	2	3	4
5. The poster is neat, presentable, readable, concise and uses appropriate language.	1	2	3	4
6. Space, colours, pictures/drawings and other devices add to the effectiveness of the poster.	1	2	3	4
7. The layout/format of the poster is effective in that the poster does not seem like a collection of information.	1	2	3	4

Comments