Mighty Morphology

Our Question: How can comparing animals' physical characteristics can help us understand their genetic relationships?

Goals:

At the end of the activity, will be able to:

- Compare the physical characteristics of insects to reinforce knowledge of biological classification
- Use a cladogram
- Infer that all animals have a common ancestry

Materials Needed:

- Insect Set 1 (Moths)
- Insect Set 2 (Crickets/grasshoppers)
- Insect Set 3 (Butterflies)
- Insect Set 4 (Dragonflies)
- Insect Set 5 (Beetles)
- *Mighty Morphology* answer key
- *Mighty Morphology* datasheet
- Cladogram

Helpful Words:

Ancestral relationship: how two or more organisms are genetically related

Characteristic: a feature or trait

Cladogram: a diagram that shows the evolutionary relationships among a group of organisms

Classification: the process of organizing or grouping organisms together based on shared characteristics

Evolution: a scientific theory that explains how life diversifies as a result of the genetic changes in a population of organisms over time resulting in changes of features or behaviors

Evolutionary tree: a diagram showing inferred ancestral relationships between organisms based upon similarities and differences in their characteristics

Morphology: the branch of biology that studies the form of living organisms and the relationships between their structures

Introduction (Read this first!):

Life comes in all shapes, colors, forms and sizes – and some living things look more alike than others. The differences and similarities in the physical characteristics of living things are important clues to help us understand not only how organisims surivive today, but also about their genetic relationship to each other. In this activity, we will use classification and cladograms to better understand what physical characteristics can tell us about the evolutionary history and relationships between different animals.

How do you think comparing animals' physical characteristics can help us understand their genetic relationships?

Before you begin, research the following terms on your own:

- Morphology
- Classification
- Ancestral relationship
- Cladogram

Check out the "Helpful Words" and "Background Information" at the end to make sure your findings are correct.

Directions:

1. Print ***Mighty Morphology* datasheet**. (You can print additional copies to complete each insect set as needed.).
2. Choose one **Insect Set** to start and print if desired.
3. Complete **Step 1:Observe!** of the **datasheet**.
4. Complete **Step 2:Think!** of the **datasheet.**
5. Print the **Cladogram** and complete **Step 3:Investigate!** of the **datasheet**.
6. Repeat with as many **Insect sets** as desired.
7. Check your answers with the ***Mighty Morphology* answer key** (located after the Background Information section.)
8. Interested in learning more? Check out the **Background Information** and **Helpful Resources** section at the end!

A

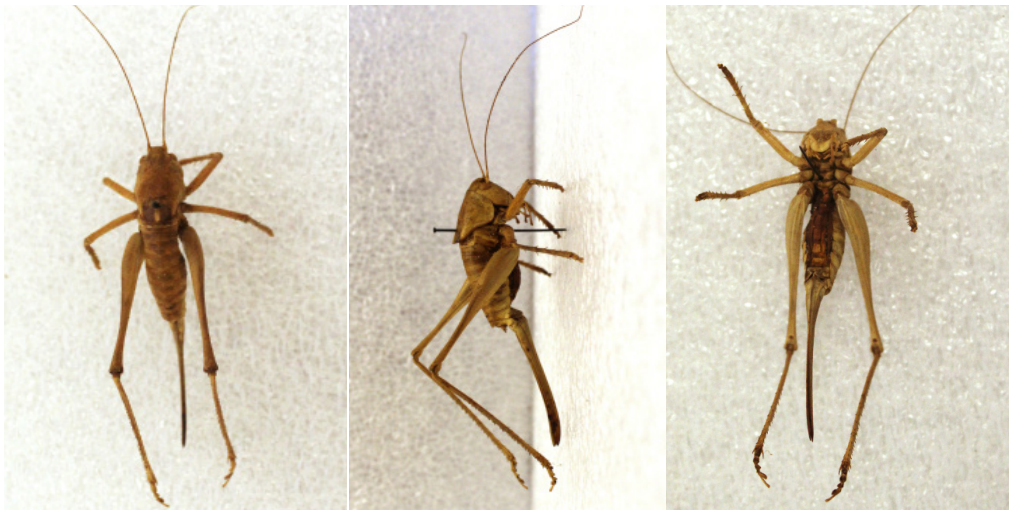
B

C

Images courtesy of the Sam Noble Museum

Insect Set 1 "Mighty Morphology"

A



B

C

Images courtesy of the Sam Noble Museum

Insect Set 2 "Mighty Morphology"

A

B

C

Images courtesy of the Sam Noble Museum

Insect Set 3 "Mighty Morphology"

A

B

C

Images courtesy of the Sam Noble Museum

Insect Set 4 "Mighty Morphology"

A

B

C

Images courtesy of the Sam Noble Museum

Insect Set 5 "Mighty Morphology"

Scientists' Names:_____ Date:_____

Mighty Morphology

Step 1: Observe!

What do you notice about the similarities and differences in the body structures of the insects?

1) List the characteristics that all three species share: _____

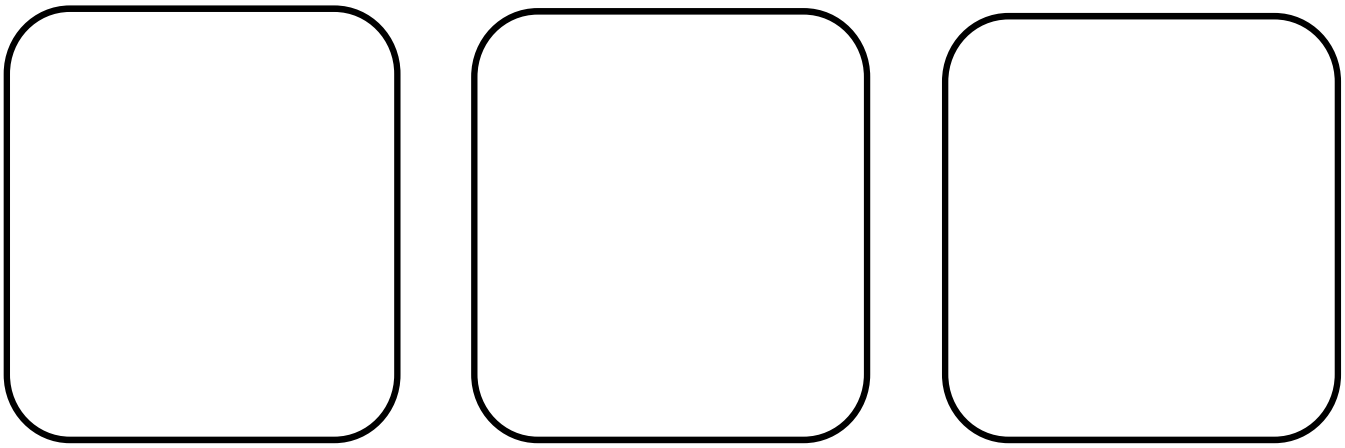
_____

_____

_____

_____

2) Draw each insect below.



A B C

3) Compare the three insects. Which two species share the most characteristics in common?

_____ and _____

4) Describe what characteristics they share that the third species does not: _____

_____

_____

_____

Step 2: Think!

Did you know? *Animals that share more genetic material in common often share more physical characteristics (they look similar). Animals that are more closely related share a more recent common ancestor. Scientists classify, or group together, animals that share many of the same features to understand how closely they are related to each other and other animals.*

For example, animals with no back-bone, an exoskeleton, three-part body and six legs are grouped together and classified in the Class Insecta. They share more genetic material and characteristics with each other than with other groups of animals (birds, reptiles, etc.) and therefore share a more recent common ancestor.

5) Which two species are the most closely related to each other? Why do you think so?_____

_____

_____

_____

Step 3: Investigate!

6) Look at the cladogram and determine how your insects are related. Were the two species that you identified in Step 2 the most closely related? How do you know? _____

_____

_____

_____

7) According to the cladogram, which species of insect is the most distantly related to your family of insects: _____

How do you know?

_____

_____

8) The beginning of the cladogram (under the label "Class: Insecta") starts with a single line. What does that represent in terms of ancestral relationship? _____

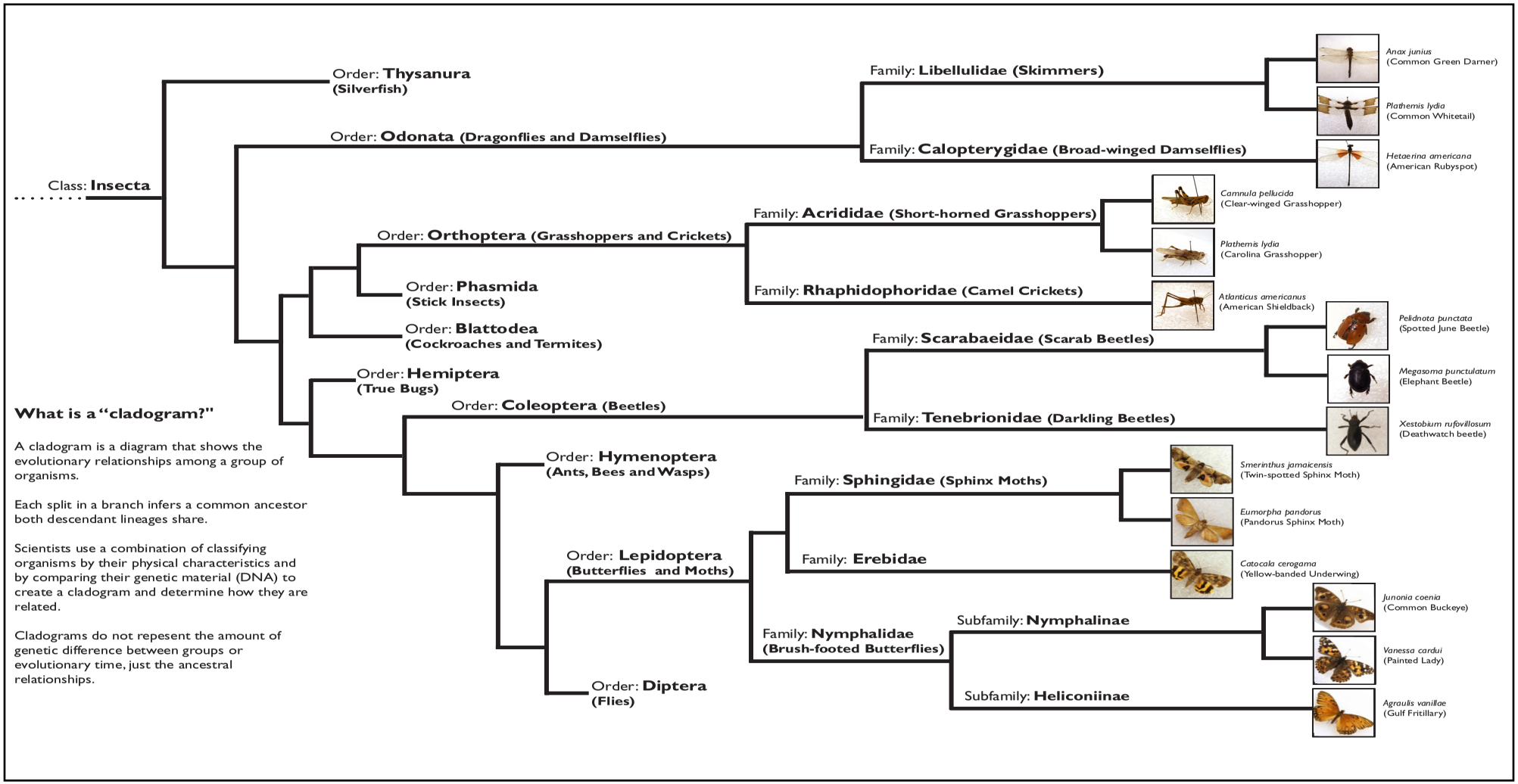
_____

_____

_____

_____

Cladogram "Mighty Morphology""



What is a "cladogram?"

A cladogram is a diagram that shows the evolutionary relationships among a group of organisms.

Each split in a branch infers a common ancestor both descendant lineages share.

Scientists use a combination of classifying organisms by their physical characteristics and by comparing their genetic material (DNA) to create a cladogram and determine how they are related.

Cladograms do not repesent the amount of genetic difference between groups or evolutionary time, just the ancestral relationships.

Background Information:

What is classification?

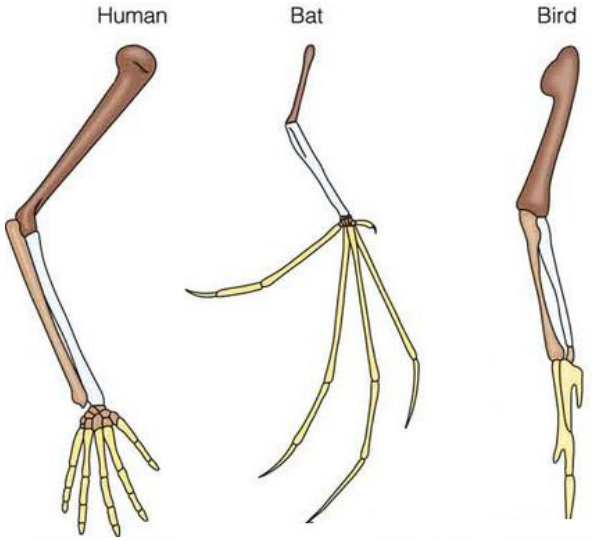
Classification of a Species Author Unknown License: CC BY-SA 3.0

Classification is the process of organizing or grouping things together based on shared characteristics. In biological science, classification (also called "taxonomy") organizes organisms into groups based on the physical features they share. With advances in genetics, scientists are now able to classify organisms by comparing the similarities in their DNA. If many different organisms have a feature in common, they are placed in a group together. The organisms in that larger group are then split into smaller groups by identifying more specific common characteristics. For example, all organisms that are multicellular, eukaryotic (have membrane-bound organelles) and heterotrophic (cannot produce their own food and must consume it) are grouped in the kingdom Animalia. All animals that have a backbone are grouped together in the phylum Chordata. All chordates that also have hair, three middle-ear bones and produce milk are grouped together into the class Mammalia. Mammals are then divided into smaller groups (Order, Family, Genus and Species). The more groups an organism shares with another organism, the more common characteristics they share (see illustration above).

Classification helps scientists organize all organisms into a standard system in order to better understand how they are interconnected and related. By identifying the shared and different characteristics of organisms, we can also learn about the evolution of modern animals and their ancestral relationships. When studying ancient animals, scientists use fossils as evidence of ancient animal characteristics. They can compare these ancient characteristics to modern animals to find links between organisms past and present.

What is an ancestral relationship?

Ancestral relationship is a term that refers to organisms who share a common ancestor (genetically) of some degree. If organisms have a more recent common ancestor, they are likely to share more genetic material and therefore more characteristics in common. Classifying organisms based on their similar characteristics is one way we can understand how closely they may be related.



Limbs by Brooks Cole Publishing License: CC BY-SA 3.0

Animals with many specific characteristics in common are likely more closely related (have a more recent common ancestor) than animals that share fewer characteristics.

For example, bats, birds and humans all have a common ancestor. They all share some characteritics like vertebrae. Bats and humans share characteristics like hair and live birth but both bats and birds have wings. How can scientists tell which of these organisms share a more recent common ancestor? One way is to compare the skeletal structures of birds, bats and humans. As seen in the model, all of these organisms have similar bones, but the structure of the carpals (wrist), metacarpals and phalanges (fingers) are more similar in bats and humans, including the presence of five fingers. These similarities indicate that the common ancestor of bats and humans is more recent than the common ancestor of birds, bats and humans.

By classifying animals, we can gain an understanding of how they are related to other living animals and how they are related to ancient animals!

What is a cladogram?

A cladogram is a diagram that shows the evolutionary relationships among a group of organisms. Each split in a branch infers a common ancestor both descendant lineages share.

In the past, biologists would group organisms based only on their physical characteristics. Today, scientists scientists use a combination of classifying organisms by their physical characteristics and by comparing their genetic material (DNA) to create a cladogram and determine how they are related.

Cladograms do not represent the amount of genetic difference between groups or evolutionary time, just the ancestor-descendant relationships.

Going Further:

What is evolution?

Evolution is a scientific theory that explains the development of and diversity of organisms in the past and in the present. Evolution explains how life diversifies as a result of the changes in the features, including DNA, or behaviors of a population of organisms over generations. These changes result in differences within a species as well as the emergence of new species. Evolutionary theory states that all life is connected and shares a common ancestry.

The way that scientists use the word "theory" is different than how it is commonly used by the general public. Most people use the word "theory" to mean an idea or assumption that someone has, but in science, the word "theory" refers to how and why something happens. A scientific theory is an explanation of some aspect of the natural world that is well supported and confirmed by evidence. This means that a theory has been significantly tested by many scientists and they have numerous examples that show that the theory holds true most of the time.

Evolution is one of the best-supported scientific theories. Scientists around the world, working in diverse disciplines such as botany, zoology, microbiology and paleontology, and over decades of research, have found abundant evidence for evolution. New technology and advances in scientific understanding of genetics and biology continue to confirm that evolution has happened in the past and continues to happen. Some of the best and easiest examples to understand are the evolution of resistance to antibiotics by various disease organisms. Evolution is important to understanding all aspects of biology including medicine and ecology.

How does evolution work?

In any given population of organisms there is variation, which means that individual organisms will have some different traits than the rest of the population. Evolution occurs when there is a change within a population over time.

The mechanisms for how a population could evolve are 1) mutation, 2) gene migration, 3) genetic drift and 4) natural selection. Mutation is a change in a DNA sequence, usually due to an error during replication or repair. Migration is when individuals from a population move into or out of a population, introducing different genetic material. Genetic drift is the random fluctuation in the numbers of gene variants in a population over time. Natural selection is how the genome of an individual interacts with its environment and how an individual with specific traits may be better able to live and reproduce in a specific environment.

What is natural selection and how does it work?

Natural selection is one of the basic mechanisms of evolution, in addition to mutation and genetic drift. Natural selection is the process by which environmental pressures such as competition for food or threat from predators cause adaptive changes in heritable traits of a population over time.

Natural selection has four components:

1. **Variation**: Individuals within populations generally differ in appearance and behavior. These variations may involve body size, coloration, markings, vocal properties or number of offspring. However, some traits show little to no variation among individuals, for example, number of eyes or legs.

2. **Inheritance**: Some traits are passed from parent to offspring. These traits are inherited traits. For natural selection to happen, traits must be heritable — passed from parent to offspring.

3. **High rate of population growth**: Most populations have more offspring each year than can survive because there are usually not enough resources (food, places to live, etc.) so only the individuals that are able to get enough of those resources survive and pass on their genes.

4. **Differential survival and reproduction**: Individuals that have traits that allow them to get the resources they need will survive and reproduce, contributing more offspring to the next generation.

What is a population?

A population is a group of individuals of the same species living and interbreeding within a given area. Populations are important for genetic diversity and variation. Larger populations generally have greater genetic diversity and show that a species is healthy. Smaller populations run the risk of low genetic variation, which can make them more vulnerable to changes in their environment.

What are traits?

Traits are characteristics or attributes of an organism that are expressed by genes. Traits include physical attributes of an organism such as hair color, leaf shape, size, etc., and behavioral characteristics, such as bird nesting.

What are genes?

Genes are areas of DNA that carry the instructions to make up the physical and behavioral components of an individual. Genes are passed on from parents to their offspring. Offspring have a combination of genes from both of their parents.

What is genetic variation?

Organisms, within populations, exhibit individual variation in appearance and behavior. These variations may involve body size, hair color, facial markings, voice properties or number of offspring. On the other hand, some traits show little to no variation among individuals, for example, number of eyes in vertebrates. Variation is important within populations because it means there are more possibilities for organisms to adapt to environmental pressures and changes.

Mighty Morphology
Answer Key

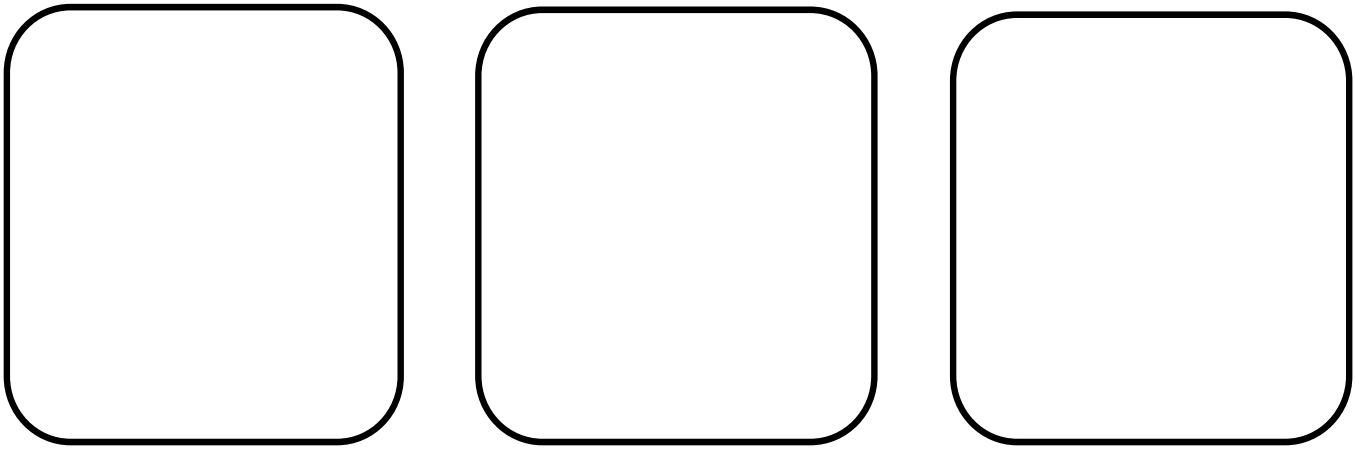
Step 1: Observe!

What do you notice about the similarities and differences in the body structures of the insects?

1) List the characteristics that all three species share:

(Answers will vary. Characteristics can include size and shape of different structures, the number of legs, pattern, color, etc.)

2) Draw each insect below.



A B C

3) Compare the three insects, which two species share the most characteristics in common?

(Answers will vary.

Hint: Look beyond size and color, as this can be variable within a single species. The three species in each set will share many characteristics in common because they all belong to the same order. In each set, two insects are from the same family or sub-family, and therefore will have a few more characteristics in common with each other than the third does not.)

4) Describe what characteristics they share that the third species does not:

(Answers will vary. Look beyond size and color, as this can be variable within a single species. The shape or proportion of different structures is a good place to start.)

Step 2: Think!

Did you know? *Animals that share more genetic material in common often share more physical characteristics (they look similar). Animals that are more closely related share a more recent common ancestor. Scientists classify, or group together, animals that share many of the same features to understand how closely they are related to each other and other animals.*

For example, animals with no back-bone, an exoskeleton, three-part body, and six legs are grouped together and classified in the Class Insecta. They share more genetic material and characteristics with each other than with other groups of animals (birds, reptiles, etc.) and therefore share a more recent common ancestor.

5) Which two species are the most closely related to each other? Why do you think so?

(Answers will vary. It is not necessary to be "correct" as long as your rationale is accurate.

X and Y species are more closely related because they share more physical characteristics in common. Animals that share more genetic material in common usually share more physical characteristics in common. Animals that share more genetic material in common, have a more recent common ancestor.)

Step 3: Investigate!

6) Look at the cladogram and determine how your insects are related. Were the two species that you identified in Step 2 the most closely related? How do you know?

(Answers will vary. Was your guess from Step 2 was correct? Whether or not your guess was correct, you can still answer the question:

Yes, the insects were part of the same family/subfamily and there was only one "branch" separating them, which means they have a more recent common ancestor that the other insect, which had two "branches" separating them.

Or:

No, the insects were not part of the same family/subfamily and there were two "branches" separating them, which means they have a more distant common ancestor. The insects that had one "branch" separating them have a more recent common ancestor.)

7) According to the cladogram, which species of insect is the most distantly related to your family of insects?
(Answers will vary.)

How do you know?
(The insects that have the most "branches" separating them means that their common ancestor is more distant and they have less genetic material in common.)

8) The beginning of the cladogram (under the label "Class: Insecta") starts with single line. What does that represent in terms of ancestral relationship?

(The line represents the common ancestor of all insects which all insects are genetically related to.)

Helpful Resources

Websites

- KidsBiology: Classification
  http://www.kidsbiology.com/biology_basics/classification/classification1.php
- Understanding Evolution: Evolution 101
  http://evolution.berkeley.edu/evolibrary/home.php
- Smithsonian Science Education Center: Evolution, Phylogenetic Trees, and Younger Audiences
  https://ssec.si.edu/stemvisions-blog/evolution-phylogenetic-trees-and-younger-audiences
- UC Berkley: Getting into the Fossil Record
  http://www.ucmp.berkeley.edu/education/explorations/tours/fossil/guide/guide.html
- Peabody Museum of Natural History: Ancestral Relationships
  http://peabody.yale.edu/exhibits/tree-of-life/what-phylogenetic-relationship

Books

- "Evolution" by Daniel Loxton
- "Prehistoric Life" by William Lindsay

Academic Standards

Oklahoma Academic Standards (OAS) - Science

Grades 9 – 12

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Biology I

HS-LS4-1: Analyze and evaluate how evidence such as similarities in DNA sequences, anatomical structures, and order of appearance of structures during embryological development contribute to the scientific explanation of biological diversity.

> Crosscutting Concepts (Patterns): Patterns can be used to identify cause and effect relationships.

HS-LS4-2: Construct an explanation based on evidence that biological diversity is influenced by (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

> Crosscutting Concepts (Cause and Effect): Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-LS4-3: Apply concepts of statistics and probability to support explanations that organisms with an advantageous trait tend to increase in proportion to organisms lacking this trait.

> Crosscutting Concepts (Patterns): Different patterns may be observed at each of the scales at which is a system is studied and can provide evidence for causality in explanations and phenomena.

HS-LS4-4: Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

> Crosscutting Concepts (Cause and Effect): Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Next Generation Science Standards (NGSS)

Grades 9 – 12

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Biology 1

HS-LS4-1: Analyze and evaluate how evidence such as similarities in DNA sequences, anatomical structures, and order of appearance of structures during embryological development contribute to the scientific explanation of biological diversity.

> Crosscutting Concepts (Patterns): Patterns can be used to identify cause and effect relationships.

HS-LS4-2: Construct an explanation based on evidence that biological diversity is influenced by (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

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