Adaptation and Evolution

Strands Life at the Systems and Organisms Level; Interaction of Life forms

Topic Investigating comparative anatomy, adaptations, and evolution

Primary SOL BIO.7 The student will investigate and understand how populations change through time. Key concepts include

a) evidence found in fossil records;
b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations;
c) how natural selection leads to adaptations;
d) emergence of new species; and
e) scientific evidence and explanations for biological evolution.

Related SOL BIO.6 The student will investigate and understand bases for modern classification systems. Key concepts include

a) structural similarities among organisms;
b) fossil record interpretation;
c) comparison of developmental stages in different organisms;
d) examination of biochemical similarities and differences among organisms.

Materials

- Copies of the seven attached handouts
- Station 1: stopwatch, empty water bottle with screw-on cap, piece of string, duct tape, running water
- Station 2: dishwashing tub, marbles, grains of rice, pieces of yarn or string, unpopped popcorn, forceps, crucible tongs, kitchen tongs, blunt pliers, four plastic cups, kitchen timer, graph paper
- Station 3: two dishwashing tubs one-quarter filled with a mixture of dark organic soil, a bag of black beans, and a bag of navy beans; two kitchen timers; two plastic cups
- Station 4: drawing and coloring utensils
- Station 5: scissors, glue, white copy paper
- Station 6: paper
- Station 7: copies of Picture A, Picture B, and other pictures C, D, E, F, and G, as specified

Vocabulary

absolute age, adaptation, analogous structures, behavioral isolation, camouflage, comparative morphology, development, directional selection, disruptive selection, divergence, DNA analysis, DNA fingerprint, embryology, evolution, extinct, fossil record, fossil, gel electrophoresis, gene pool, genetic drift, geographic isolation, homologous structures, Law of Superposition, mimicry, natural selection, parapatric speciation, relative age, reproductive isolation, resistance, speciation, stabilizing selection, variation, vestigial, vestigial structures

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)
In this lesson, students will investigate visually, verbally, and kinesthetically comparative anatomy of organisms and how these organisms have changed through adaptation and evolution. To meet this objective, each group of students will perform seven independent activities at seven separate stations.

This lesson is designed to be accomplished in two 90-minute blocks with the groups working simultaneously at the seven stations for about 20 to 25 minutes each. Some activities are to be done collaboratively by the group members, while others are to be done individually. You may want to have students refer to a visible clock to keep track of the time.

Prior to the class, set up each station in an appropriate place in the classroom with all the materials needed for the station's activity.

(As an alternative to having students do the experiments presented on the handouts, Socratic questioning could be used to *guide* students in designing solid experiments themselves, similar to the given ones.)

1. Give each student a copy of the activity sheets for all seven stations.
2. Form seven groups of students. (See first strategy under Strategies for Differentiation below.)
3. Assign each group to a station, where they will find the materials needed to complete the station's activity. Allow students 20 to 25 minutes to work in their groups to complete the activities at their various stations. As students work, circulate and facilitate their work by answering and asking questions, making clarifications, and offering other assistance.
4. When time is up, direct groups to rotate to the next stations and complete their new activities. Again, allow 20 to 25 minutes for students to complete the activities. Continue having groups rotate among the stations until all groups have completed all activities.

Assessment

- Use completed activity sheets for assessment.

Extensions and Connections (for all students)

- For a great pre-learning or during-learning activity, show a short video on adaptations, evolution, or comparative anatomy. One possibility is "By Land or by Sea – Comparative Anatomy" (available at http://www.sosq.vcu.edu/videos.aspx; click on "Anatomy"). Be sure to preview any video first. After students view the video, hold a brief discussion about it, pointing out key vocabulary and questioning students about important content.
- Have students read the article "Fire ants invade and evolve" (available at http://evolution.berkeley.edu/evolibrary/article/0_0_0/fireants_01) and then write responses to the questions "How does natural selection work? How does natural selection favor different genes based on environmental condition?"

Strategies for Differentiation

- Employ flexible groupings of students by grouping them according to common readiness levels, shared interests, or diverse strengths.
- Create compare-contrast diagrams and graphic organizers for students to use.

- Direct high level students to make their own data charts and give more examples.
- Use writing prompts with essential questions to apply concepts to real-world applications.
- Allow students to record their input instead of writing.
- Differentiate the writing portions of the activities by having students complete them either as a group, individually in class, or for homework. As a group assignment, roles could be assigned within each group so that one student is the recorder who does the writing, another is the discussion leader, a third is the timekeeper, and a fourth is the proofreader.

Station 1: Homologous Structures

Introduction

In this activity, you will simulate how different organisms have adapted to their environments while maintaining some similarities among certain of their anatomical features. You will perform an experiment to compare the anatomies and uses of three appendages—a human hand, a dog paw, and a whale flipper. You will fill in data tables and answer questions about the experiment.

Materials

Stopwatch, empty water bottle with screw-on cap, piece of string, duct tape, running water

Procedure

1. Each member of the group does one of the following tasks, and another person times how many seconds it takes to complete the task. Each person records the times opposite "Open hand" in the data table below.
   - Unscrew and screw back on the cap of an empty water bottle
   - Tie and untie a knot in a piece of string
   - Perform a daily task of your choice (e.g., put jewelry on and take it off, tie and untie a shoe lace)
2. The group goes to a source of running water, and one person catches as much water as possible in a single, open hand with fingers spread wide. Each person records the amount of water (very little, some, a lot) opposite "Open hand" in the data table below.
3. One person uses a foot-long piece of duct tape to wrap around the middle of one hand, fastening his/her thumb securely to the side of the hand. The thumb should be totally unusable, but the other fingers should still be spreadable. Procedures 1–4 are repeated.
4. Another person uses another piece of duct tape to securely tape all fingers of one hand together so he/she cannot spread or use any fingers or thumb at all. Procedures 1–4 are repeated.
5. Based on all observations, each person fills in the data table on the next page and then answers all the questions.
6. The group resets the station, leaving it for the next group exactly like they found it.

Type of appendage	Time to screw cap off and on	Time to tie and untie knot	Time to perform chosen activity	Amount of water in hand
Open hand with spread fingers				
Open hand with spread fingers but no thumb				
Closed hand with no fingers or thumb				

Station 1: Homologous Structures, continued

Type of appendage	In what kind of environment does this organism live?	What is this appendage best at doing? Describe.	What kind of food does this organism eat? Does it use this appendage to catch food?
Whale flipper			
Human hand			
Dog paw			

Questions

1. What was the chosen activity? Why was it chosen?

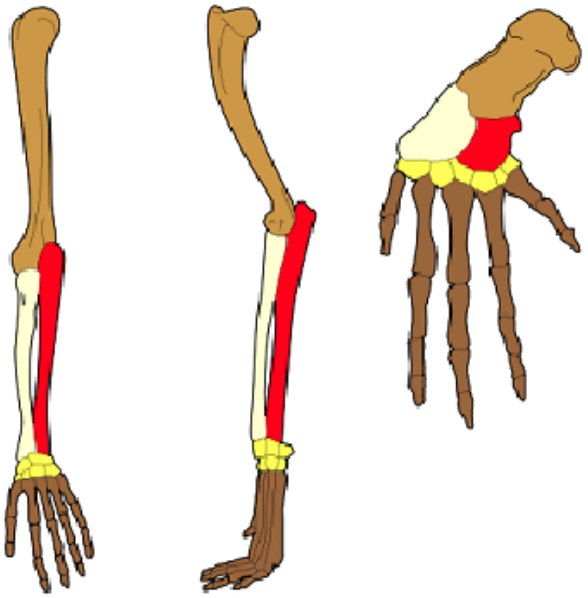
2. What was difficult to do with the thumb taped? With all fingers taped? Explain.

3. If an appendage can hold water well, what does that mean?

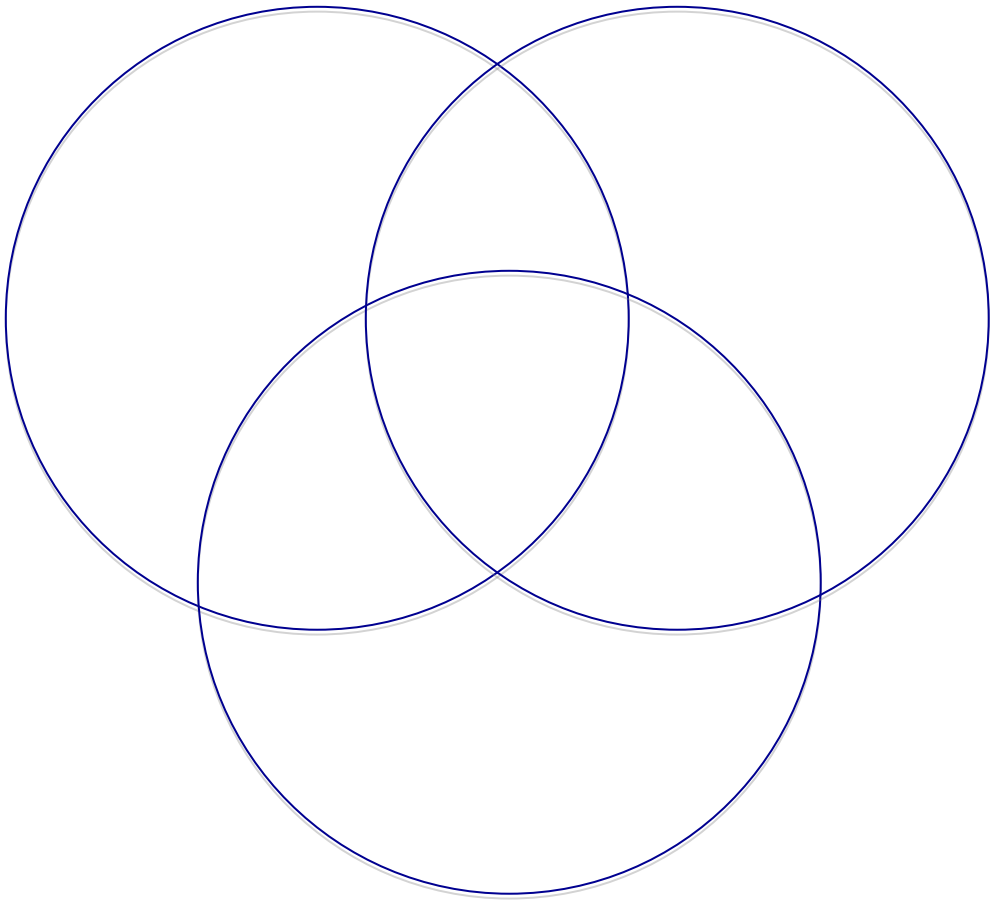
4. Which example above represented the whale flipper? _____
   Which example above represented the human hand? _____
   Which example above represented the dog paw? _____

5. Why are these anatomical features considered homologous?

6. Examine the pictures below of the anatomical features of the whale flipper, human hand, and dog paw. Below the drawings, create a triple Venn diagram based on your observations, explaining the similarities and differences among the three appendages.



Human Dog Whale



Station 2: Darwin's Finches

Introduction

On Charles Darwin's famous voyage to the Galapagos Islands, he studied many different species of organisms, one of which was the finch. He noticed that these finches had many different beak styles, the style seemingly being dependent on the type of food readily available to each finch.

In this activity you will simulate how finches with different beak styles compete for food and are successful at eating various different types of food. You will compare four different beak styles:

- Long, thin, pointy beaks
- Medium, long, pointy beaks
- Fat, long beaks
- Fat, thick, short beaks

Each group member will represent a finch with a different beak style.

Materials

Dishwashing tub, marbles, grains of rice, pieces of yarn or string, unpopped popcorn, forceps, crucible tongs, kitchen tongs, blunt pliers, four plastic cups, kitchen timer, graph paper

Procedure

1. The group puts the marbles, grains of rice, pieces of yarn or string, and unpopped popcorn in the dishwashing tub. Each person takes an empty plastic cup and a different tool (forceps, crucible tongs, kitchen tongs, or blunt pliers) to use. These tools represent different beak styles.
2. One person sets the timer to two minutes. Each person uses his/her tool to pick up as many objects in the tub as possible in two minutes and put them in his/her plastic cup.
3. At the end of two minutes, group members stop and count how many of each object they picked up successfully. They record the totals for their tools in their data table below.
4. The group members then share their data with each other so that each person can complete his/her data table.
5. Based on the data, each person then answers all the questions found on the next page.
6. The group resets the station, leaving it for the next group exactly like they found it.

Tool	Beak type	Number of marbles	Number of rice grains	Number of popcorn kernels	Number of string pieces
Forceps					
Crucible tongs					
Kitchen tongs					
Blunt pliers					

Station 2: Darwin's Finches, continued

Questions

1. What tool did you use in this activity? What did it represent?

2. What did each of the other tools represent?

3. Using a piece of graph paper, create a graph of the data for your tool.
4. Using your graph, answer the following questions:
   a. What item(s) could you pick up more often? Why?

   b. What item(s) could you pick up less often? Why?

Essay

Write a short essay that begins with the sentence, "When Darwin was studying animals in the Galapagos Islands, he discovered 13 different species of finches, each with a different beak type and method of obtaining food." In your essay,

- explain how the finches are an example of divergence
- explain how an entire population can adapt in response to a changing environment
- explain how if a new food source appears in the environment, that could cause the emergence of a new species.

Use all of the following vocabulary in your essay:

- *natural selection*
- *genetic diversity*
- *variation*
- *adaptation*
- *divergence*
- *speciation*
- *geographic isolation*
- *parapatric speciation*
- *divergence*

Station 3: Now You See It, Now You Don't

Introduction

In this activity, you will simulate natural selection. If organisms were *not* to adapt to their environments, they would become extinct. A famous example of natural selection is that of the peppered moth. In a scientific study of the population of peppered moths, it was discovered that before the Industrial Revolution, the moths were a light color because the trees and other vegetation were light in color, but as soon as industry polluted the vegetation in an area, causing trees and other plants to become darker from wastes, the moths, too, started to become darker.

Materials

Two dishwashing tubs one-quarter filled with dark organic soil, a bag of black beans, and a bag of navy beans; two kitchen timers; two plastic cups

Procedure

1. The group divides up into pairs. Each pair decides who will be the "moth eater" and who will count the number of moths eaten. (Of course, the moths are not real, and no one will eat anything. The activity is a simulation!)
2. Each pair sets a timer to two minutes. Each "moth eater" sifts through his/her soil and picks out as many white and black beans as he/she can find in two minutes, placing them in a plastic cup. The beans represent peppered moths.
3. At the end of two minutes, the "moth eaters" stop, and the counter counts the number of moths his/her partner "ate." The counter fills in the data table below, and then shares the data with his/her partner. Then the pairs in the group share their data with each other.
4. Based on the data, each person then answers all the questions found below.
5. The group resets the station, leaving it for the next group exactly like they found it. Be sure to mix all the beans into the soil completely.

Pair	Number of dark moths (black beans) eaten	Number of light moths (navy beans) eaten
1		
2		
Average		

Questions

1. How does the average number of dark moths compare to the average number of light moths?

_____

Essay

Write a short essay that begins with the sentence, "The scientific study of the population of peppered moths showed that the light moth population became smaller and smaller over time." In your essay, explain how the gene for dark color in peppered moths might have developed. How would Darwin have explained the changes in the number (population) of light moths in the

Station 3: Now You See It, Now You Don't, continued

polluted, darkened forest of their environment. What are some other examples of another organism's population changing and adapting because of environmental pressures? Use all of the following vocabulary in your essay:

- *genetic variation*
- *mimicry*
- *camouflage*
- *extinct*
- *natural selection*
- *directional selection*
- *disruptive selection*

Station 4: The Perfect Animal and Its Adaptations

Introduction

In this activity, you will work individually to design an imaginary animal, basing it on a given habitat in which it must survive and thrive. Below are the possible habitats of your animal:

1. This habitat is humid and has very warm temperatures. There are numerous plants with thick, green vegetation, like a rain forest. There are rolling hills and valleys. The scenery is very tropical and beautiful. There are plenty of freshwater rivers and streams but no bodies of salt water for miles. Most of the predatory animals are on the ground, and even some of the vegetation is carnivorous.
2. This habitat is blistering cold and dry, with freezing temperatures most all the time. There is very little vegetation, for this habitat consists mainly of snowy dunes and ice. There are very few organisms living in this habitat because of the harsh conditions. There is little sunlight year round.
3. This habitat has a moderate temperature all year round. It is an aquatic habitat in a salt-water environment. There are plenty of aquatic plants and other organisms of all trophic levels.
4. This habitat is dry and has hot temperatures. There is no nighttime in this environment, so it is light all of the time. There are few water sources close by, and there is also very little vegetation.

Materials

Drawing and coloring utensils

Procedure

1. Select one of the habitats described above. Make sure each member of your group selects a different habitat so that all habitats are selected.
2. Answer the questions below, and then draw your perfect animal on the back of this sheet.

Questions

1. My animal lives in habitat number _____.
2. The common name of my animal is _____.
3. How does your animal eat?

   _____
4. Does it have teeth? _____ If so, what do they look like?

   _____
5. What kind of food does your animal eat?

   _____

Station 4: The Perfect Animal and Its Adaptations, continued

6. What kind of skin or outer protection does your animal have? Explain why.

_____

7. Is your animal a vertebrate or an invertebrate? _____
8. How does your animal move?

_____

9. How does your animal protect itself?

_____

10. What are the mating behaviors of your animal?

_____

11. How does your animal reproduce?

_____

12. How many offspring does your animal usually have?

_____

13. How large is your animal?

_____

14. What are three of your animal's adaptations that enable it to survive in this habitat?

_____

_____

15. If a natural disaster were to occur in your animal's habitat, what adaptations might develop over time? Give an example of a natural disaster and what would happen.

_____

_____

16. If your animal's main food source were disappear in its habitat, what adaptations might your animal develop over time?

_____

_____

17. Is reproduction vital to just your animal's survival? _____ Is it vital to the population of this species? _____ Explain your response.

_____

_____

18. On the back of this sheet, draw your animal with as much detail as possible. Label its anatomical features that make it unique.

Station 5: Fossils, the World's History Book

Introduction

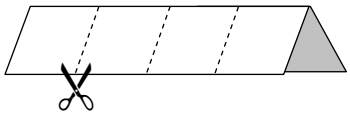
In this activity, you will work individually to interpret pictures of fossils and explain how organisms have adapted over time, using fossil evidence. You will create a foldable, using these pictures, and answer the given questions.

Fossils are like a history book of the world—nature's way of describing the past. We can make observations of fossils in order to formulate hypotheses about the kinds of environments the organisms lived in, their anatomical features, how they compared to other organisms of the time, and the organisms that proceeded them. We can also determine the approximate ages of the fossils.

Unfortunately, fossils cannot give us all the information we would like to have. Most fossil records are incomplete, so much educated guessing and putting together of missing pieces are required.

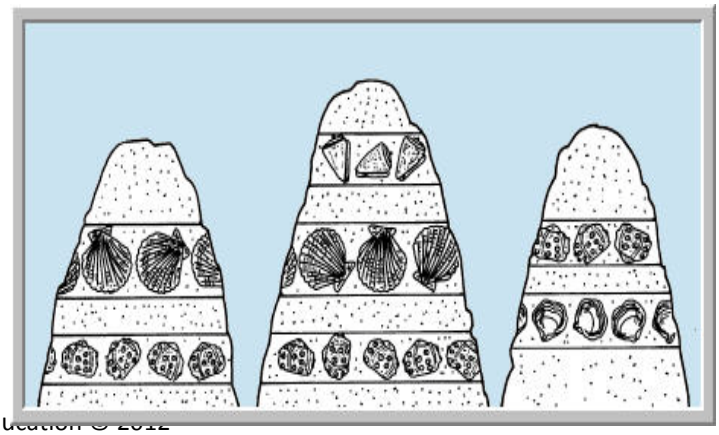
Materials

Scissors, glue, white copy paper

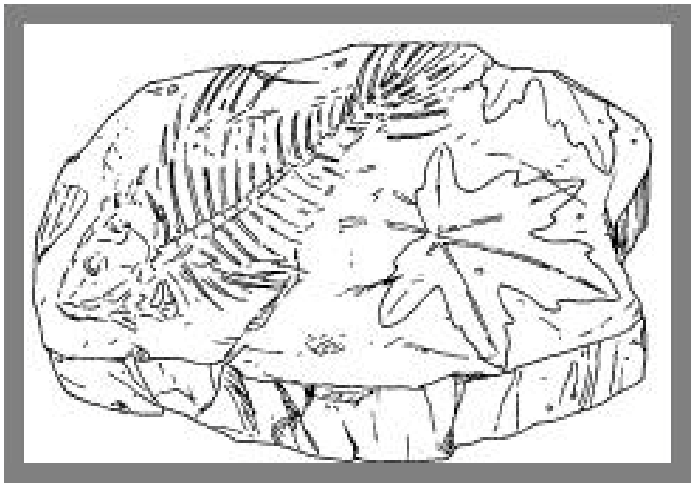


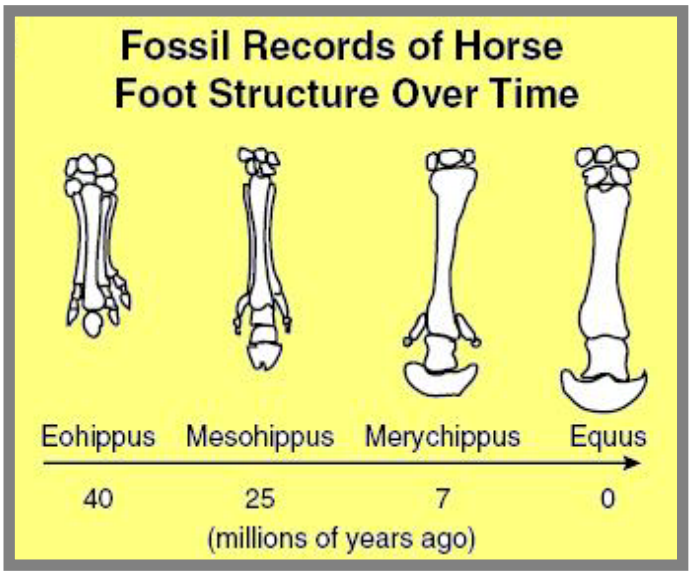
Procedure

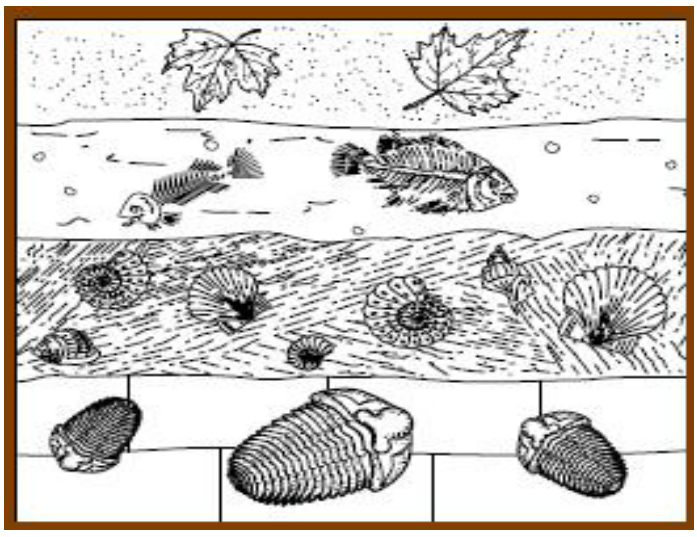
1. Fold a sheet of white paper in half lengthwise, or "hotdog style" (see above); then, fold it in half from side to side, or "hamburger style," *twice*. Unfold the last two folds; this will give you a total of four boxes (sheet is still folded in half length-wise, or "hotdog style").
2. Use scissors to cut along the creases from one edge up to the lengthwise fold, making four flaps on one-half of the folded sheet.
3. Cut out the four pictures below, and glue them on the fronts of the four flaps.
4. Open each flap, and answer inside the following questions for each picture. Write answers in complete sentences.
   a. How would you go about scientifically determining the age of this fossil? Explain in detail.
   b. What kind of organism(s) does this fossil represent (e.g., marine, freshwater, plant, arthropod)?
   c. What were some anatomical features of this organism(s)? If more than one organism, list features of each.
   d. What kind of habitat(s) did the organism(s) live in?
   e. How could you determine which organisms are the oldest by looking at this fossil?



Station 5: Fossils — The World's History Book, continued







Station 6: Are We Related? Comparative Anatomy

Introduction

In this activity, you will work individually to examine the anatomical structures of different organisms in order to compare and contrast them. You will focus on two opposite types of anatomical structures: homologous structures and analogous features.

Homologous structures have the same origin and may look similar (have similar structures), but they do not have a common function.

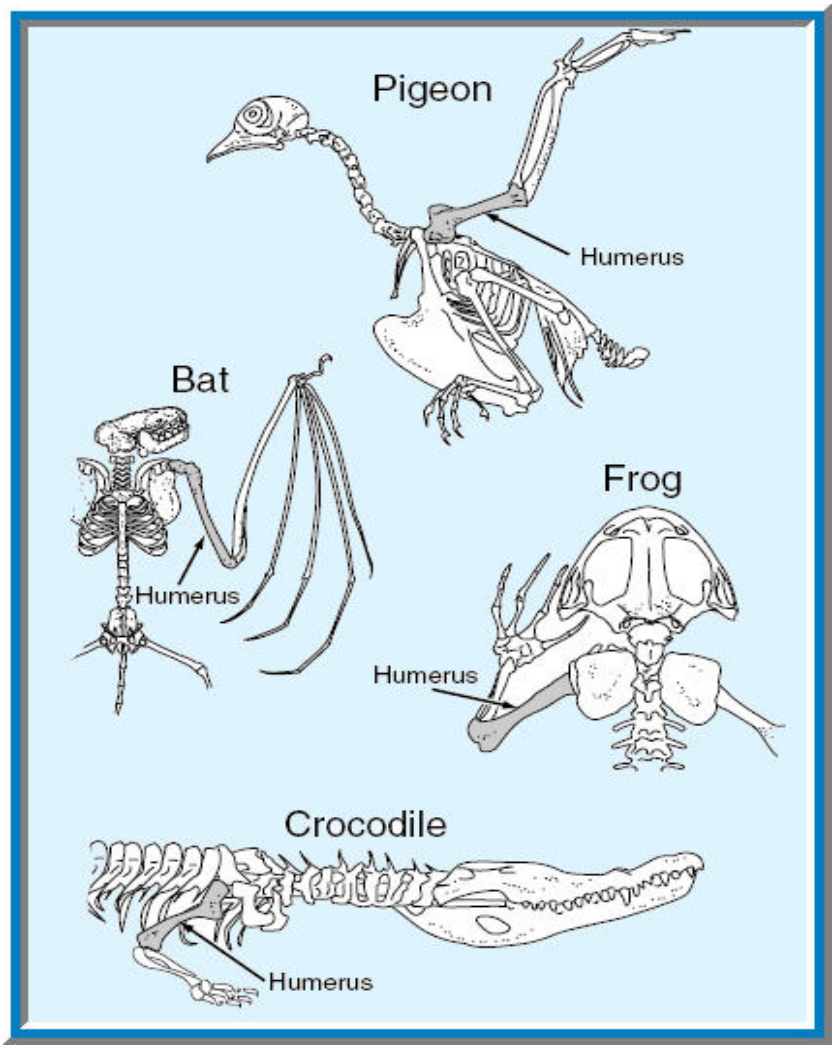
Analogous structures have a common function, but they do not have the same origin and do not look similar (have different structures).

Materials

Paper, Internet access

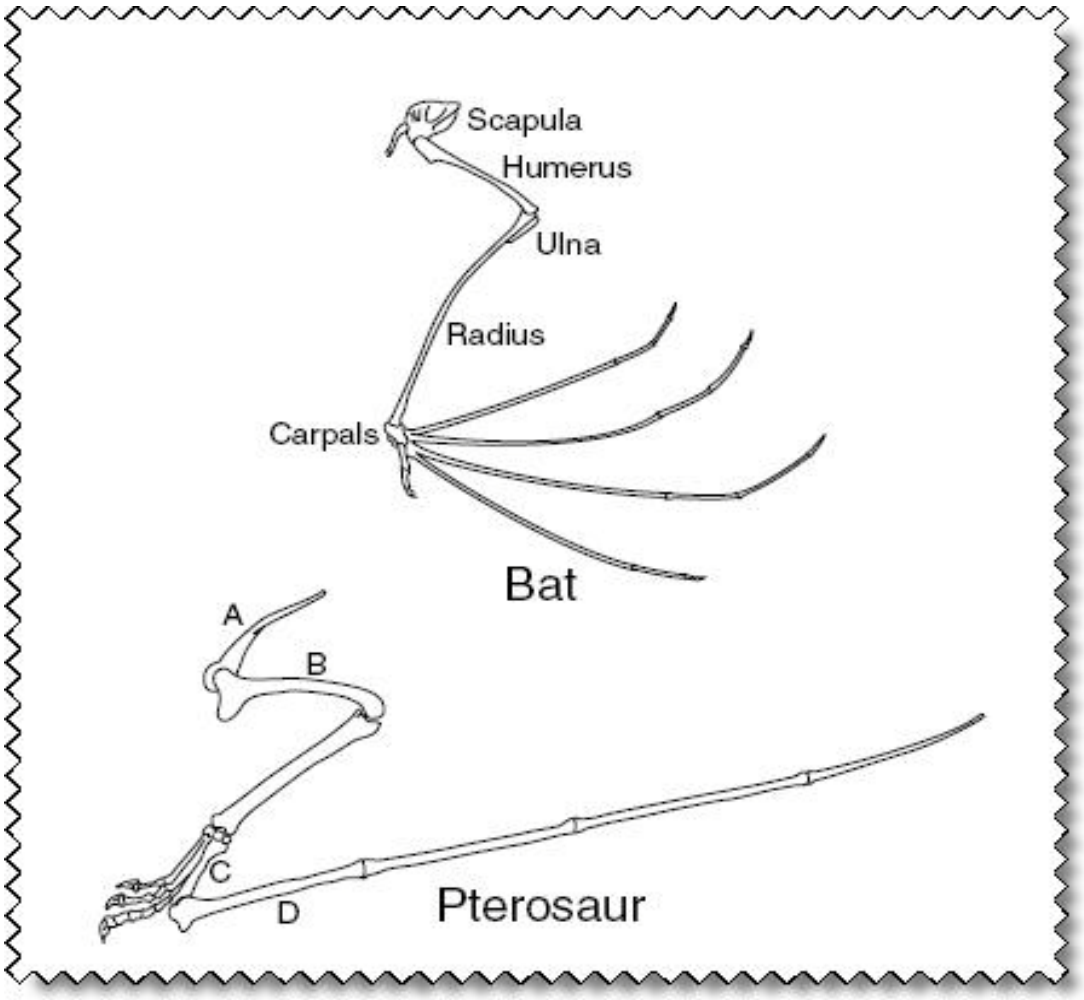
Procedure

1. Examine Pictures A and B. For each picture, create a graphic organizer, Venn diagram, or chart describing the anatomical structures featured and the similarities and differences between these structures. You may use a separate sheet of paper for each picture.
2. Identify the type of anatomical structures represented by each picture—homologous or analogous. At the bottom of each page, explain why you came to that conclusion.
3. Search the Internet for drawings of a bat wing, a butterfly wing, and a bird wing. These will be "Picture C." Repeat steps 1 and 2 for Picture C.
4. Give an example of a vestigial structure, and explain why it is considered vestigial.



Picture A

Station 6: Are We Related? Comparative Anatomy, continued



Picture B

Station 7: A Picture Is Worth a Thousand Words

Introduction

In this activity, you will interpret what you and the other members of your group observe in a series of pictures. Your group will then answer questions about each picture and discuss the answers based on your knowledge of the picture and your observations.

Materials

Various pictures, as described below

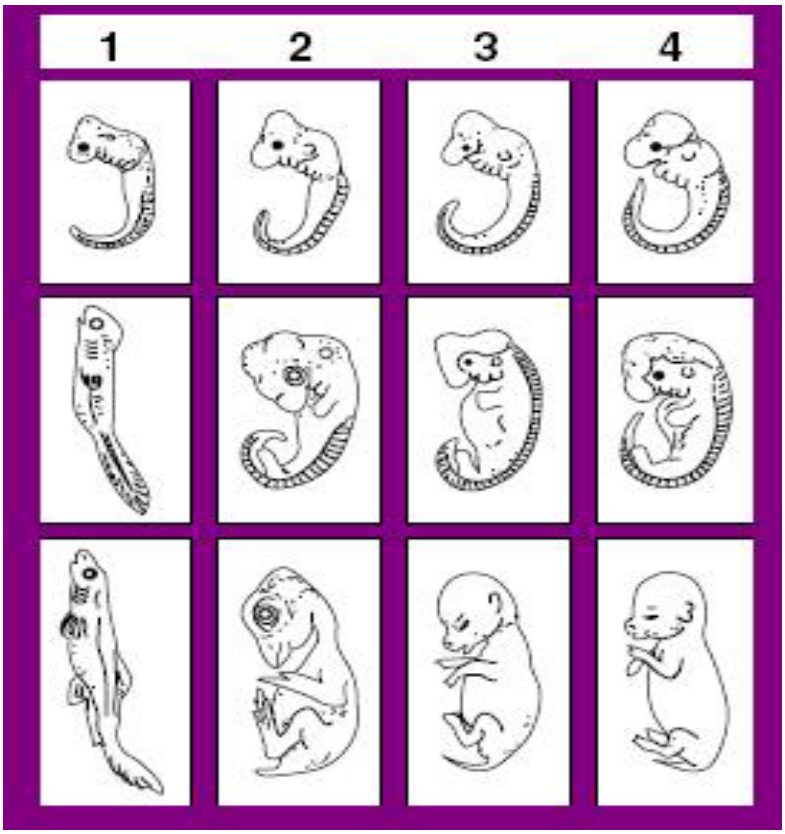
Procedure

1. Examine Picture A, and discuss with your group what you see in it. Be specific.
2. Read each question for that picture, and then brainstorm with your group possible answers and conclusions based on your observations.
3. Write down your group's answers to the questions. Everyone in your group should write exactly the same answers.
4. Repeat steps 1–3 for the remaining five pictures.

Questions

Picture A: Embryological development

1. Examine the picture at right, and describe what it shows.
2. How many different organisms are represented?
3. Look at the first stage of development for each organism. What conclusions can you make from your observations?
4. Look at the last stage of development for each organism. What conclusions can you make from your observations?
5. Based on your observations of this picture from left to right, what is the first, second, third, and fourth organism?
6. Based on your observations of this picture, can you assume that these organisms came from a common ancestor or are somehow related? Explain your response.



Station 7: A Picture Is Worth a Thousand Words, continued

Picture B: DNA analysis of three organisms

DNA Base Sequence Comparison	
Human	AGG CAT AAA CCA ACC GAT TAA
Chimpanzee	AGG CCC CTT CCA ACC GAT TAA
Gorilla	AGG CCC CTT CCA ACC AGG CCA

1. Examine the picture at right, and describe what the table shows.
2. What do the letters represent?
3. What two organisms are the most closely related? Explain your response.
4. What is another example of an organism that would have similar DNA to these organisms? Explain your response.
5. What is the best and most accurate method for determining how closely related organisms are?

Picture C: A fish and a whale

1. Examine the picture carefully. Are these organisms vertebrates or invertebrates? Explain your response.
2. Construct a T-chart listing at least five similarities and five differences between these organisms. (Hint: Consider their anatomical features and their life processes.)
3. Do you think these organisms are closely related to each other? Explain your response.

Picture D: A frog and a snake

1. Examine the picture carefully. Are these organisms vertebrates or invertebrates? Explain your response.
2. Construct a T-chart listing at least five similarities and five differences between these organisms. (Hint: Consider their anatomical features and their life processes.)
3. Do you think these organisms are closely related to each other? Explain your response.

Picture E: An insect (arthropod) and a worm (annelid)

1. Examine the picture carefully. Are these organisms vertebrates or invertebrates? Explain your response.
2. Construct a T-chart listing at least five similarities and five differences between these organisms. (Hint: Consider their anatomical features and their life processes.)
3. Do you think these organisms are closely related to each other? Explain your response.

Picture F: An apple (deciduous) and a pine cone (coniferous)

1. Examine the picture carefully. Are these organisms vertebrates or invertebrates? Explain your response.
2. Construct a T-chart listing at least five similarities and five differences between these organisms. (Hint: Consider their anatomical features and their life processes.)
3. Do you think these organisms are closely related to each other? Explain your response.
4. How did you participate in this brainstorming discussion?