**Canon Paleontology Curriculum**
**Unit 3: Evolution**

**Background Material**

**Excerpts from:**
**National Science Foundation, Teaching About Evolution and the Nature of Science, National Academy Press, 1998,**
**ISBN 0-309-06364-7**

The concept of evolution has an importance in education that goes beyond its power as a scientific explanation. All of us live in a world where the pace of change is accelerating. Today's children will face more new experiences and different conditions than their parents or teachers have had to face in their lives.

The story of evolution is one chapter -- perhaps the most important one – in a scientific revolution that has occupied much of the past four centuries. The central feature of this revolution has been the abandonment of one notion about stability after another: that the earth was the center of the universe, that the world's living things are unchangeable, that the continents of the earth are held rigidly in place, and so on. Fluidity and change have become central to our understanding of the world around us. To accept the probability of change – and to see change as an agent of opportunity rather than as a threat – is a silent message and challenge in the lesson evolution.

Evolution means a process of change, an unfolding. The world around us changes. This is a simple fact is obvious everywhere we look. Streams wash dirt and stones from higher places to lower places. Untended gardens fill with weeds.

Other changes are more gradual but much more dramatic when viewed over long time scales. Powerful telescopes reveal new stars coalescing form galactic dust, just as our sun did more than 4.5 billion years ago. The earth itself formed shortly thereafter, when rock, dust, and gas circling the sun condensed into the planets of our solar system. Fossils of primitive microorganisms show that life emerged on earth by about 3.8 billion years ago.

Many kinds of cumulative change through time have been described by the term "evolution," and the term is used in astronomy, geology, biology, anthropology, and other sciences. The ancient Greeks were already speculating about the origins of life and the changes in species over time. More than 2,500 years ago, the Greek philosopher Anaximander thought that a gradual evolution had created the world's organic coherence from a formless condition, and he had a fairly modern view of the transformation of aquatic species into terrestrial ones.

Charles Darwin and Alfred Russel Wallace were both deeply influenced by the realization that, even though most species produce an abundance of offspring, the size of the overall population usually remains about the same. Thus, and oak tree might produce many thousands of acorns each year, but few, if any, will survive to become full-grown trees.

Darwin proposed that there will be differences between offspring that survive and reproduce and those that do not. In particular, individuals that have heritable characteristics making them more likely to survive and reproduce in their particular environment will, on average, have a better chance of passing those characteristics on to their own offspring. In this way, as many generations pass, nature would select those individuals best suited to particular environments, a process Darwin called natural selection. Over very long times, Darwin argued, natural selection acting on varying individuals within a population of organisms could account for all the great variety of organisms we see today, as well as for the species found as fossils.

One common misconception among students is that individual organisms change their characteristics in response to the environment. In other works, students often think that the environment acts on individual organisms to generate physical characteristics that can then be passed on genetically to offspring. But selection can work only on the genetic variation that already is present in any new generation, and genetic variation occurs randomly, not in response to needs of a population or organism. In this sense, as Francois Jacob has written, evolution is a “tinkerer, not an engineer.” Evolution does not design new organisms; rather, new organisms emerge from the inherent genetic variation that occurs in organisms.

Genetic variation is random, but natural selection is not. Natural selection tests the combinations of genes represented in members of a species and allows to proliferate those that confer the greatest ability to survive and reproduce. In this sense, evolution is not the simple product of random chance.

The booklet *Science and Creationism: A view form the National Academy of Sciences* summarizes several compelling lines of evidence that demonstrate beyond any reasonable doubt that evolution occurred as a historical process and continues today. In brief:

- Fossils found in rocks of increasing age attest to the interrelated lineage of living things, from the single-celled organisms that lived billions of years ago to *Homo sapiens.* The most recent fossils closely resemble the organisms alive today, whereas increasingly older fossils are progressively different, providing compelling evidence of change through time.

- Even a casual look at different kinds of organisms reveals striking similarity among species, and anatomists have discovered that these similarities are more than skin deep. All vertebrates, for example, from fish to humans, have a common body plan characterized by a segmented body and a hollow main nerve cord along the back. The best available scientific explanation for these common structures is that all vertebrates are descended form a common ancestor species and that they have diverged through evolution.

- In the past, evolution relationships could be studied only by examining the consequences of genetic information, such as the anatomy, physiology, and embryology of living organisms. But the advent of molecular biology has made it possible to read the history of evolution that is written in every organism's DNA. This information has allowed organisms to be placed into a common evolutionary family tree in a much more detailed way than possible from previous evidence. For example comparisons of the differences in DNA sequences among organisms provide evidence for many evolutionary events that cannot be found in the fossil record.

Evolution is the only plausible scientific explanation that accounts for the extensive array of observations summarized above. The concept of evolution through random genetic variation and natural selection makes sense of what would otherwise be a huge body of unconnected observations. From the cumulative evidence presented by scientists, it is no longer possible to sustain scientifically the view that the living things we see today did not evolve from earlier forms or that the human species was not produced by the same evolutionary mechanisms that apply to the rest of the living world.

The following websites may be helpful for information and activities on the Nature of Science, Evolution, and geology in general.

U.S. Geological Survey website (look for education)
http://www.usgs.gov

University of California Museum of Paleontology
http://www.ucmp.berkeley.edu

University of Indiana
http://www.indiana.edu

# Canon Paleo Curriculum
# Unit: 3 Evolution

**Introduction to Unit 3**

Adaptations
Evolutionary Process
Making Molds of Fossils

1. **Possible slide show on how fossil tell us about past life**
2. **Learning Tree – adaptation Activity**
3. **Evolution of Barbellus**
4. **Barbellus presentations**
5. **Caminalcules – A**
6. **Caminalcules - B**
7. **Make fossil Casts**
8. **Who Am I? – Worksheet and Key**
9. **Chocolate Candy Recipe**
10. **How Do Fossils Show Change?**

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 2

## Activity Name: Fashion a Fish Overview

Adapted from Project Wild Aquatic

**Grades:** 9-10

**Objectives:** Students will describe adaptations of fish to their environments, describe how adaptations can help fish survive in their habitat and interpret the importance of adaptations of animals. The major purpose of this activity is for students to investigate the concept of adaptation in fish.

**State Standard Met:** Science 3.1, 3.4

**Materials:** Five cards for each adaptations from the masters provided, mouth, body shape, coloration, reproduction, art materials, paper.

**Background:** Aquatic animals are the product of countless adaptations over long periods of time. These adaptations, for the most part, are features that increase the animals' likelihood of surviving in their habitat.

When a habitat changes, either slowly or catastrophically, the species of with adaptations that allow them many options are the ones most likely to survive. Some species have adapted to such a narrow range of habitat conditions that they are extremely vulnerable to change. They are usually more susceptible than other animals to death or extinction.

In this activity, the students design a kind of fish. They choose the adoptions that their fish will have. Each choice they make would actually take countless years to develop. As these adaptations become part of the fish's design, the fish becomes better suited to the habitat in which it lives. Because of the variety of conditions within each habitat, many different fish can live together and flourish.

The major purpose of this activity is for students to investigate the concept of adaptation.

## Lesson Plan:

1. Conduct a class discussion on the value of different kinds of adaptations in animals and plants. As a part of the discussion ask students to identify different kinds of adaptations in humans. As a group, categorize these adaptations into the following groups: protective coloration and camouflage, body shape/forrr4 mouth type/feeding behavior, reproduction/behavior, response to heat/cold, response to dryness. Have students come up with other categories into which their organisms might fall.
2. Divide the adaptation cards into five groups of four cards each, one each of coloration, mouth type, body shape and reproduction.

3. Pass one complete set of cards to each group of students. There might be five groups with four to six students in each group.

4. Ask students to “fashion a fish7' from the characteristics of the cards in the set they receive. Each group should create an art form that represents their fish, name the fish using appropriate binomial nomenclature, describe and draw the habitat for their fish.

5. Ask each group to report to the rest of the class about the attributes of the fish they have designed, including identify and describing its adaptations. Ask the students to describe how this kind of fish is adapted for survival.

6. Discuss as a group, the importance of adaptations in fish and other organisms and the process by which this might occur.

**FASHION A FISH**
**Adapted from Project Wild Aquatic**

**OBJECTIVES**

**Skills:**
Students will: 1) describe adaptations of fish to their environments; 2) describe how adaptations can help fish survive in their habitat; and 3) interpret the importance of adaptations in animals.

**Method:**
Students design a variety of fish adapted for various aquatic habitats.

**Background:**
Aquatic animals are the product of countless adaptations over long periods of time. These adaptations, for the most part, are features that increase the animals likelihood of surviving in their habitat.

When a habitat changes, either slowly or catastrophically, the species of animals with adaptations that allow them many options are the ones most likely to survive. Some species have adapted to such a narrow range of habitat conditions that they are extremely vulnerable to change. They are over-specialized and are usually more susceptible than other animals to death or extinction.

In this activity, the students design a kind of fish. They choose the adaptations that their fish will have. Each choice they make would actually take countless years to develop. As these adaptations become part of the fish's design, the fish becomes better suited to the habitat in which it lives. Because of the variety of conditions within each habitat, many different fish can live together and flourish. Some adaptations of fish are shown in the table that follows.

**Subject:** Science, Art
**Skills:** analysis, application, classification, communication, description, drawing, identification, inference, invention, public speaking, reporting. smallgroup work
**Duration:** two 30 to 45-minute periods for older students; one or two 20-minute periods for younger students
**Group Size:** any; groups of four students each
**Setting:** indoors or outdoors
**Key Vocabulary:** adaptation, coloration, camouflage
**Appendices:** local resources

**Materials:**
Five cared for each adaptation from the maters povided: Mouth body shape, coloration, reproduction; art materials; paper.

**NOTE:** Body shape and coloration are the only cards needed for younger students.

Activity

1. Assign students to find a picture or make a drawing of a kind of animal that has a special adaptation for example, long necks on giraffes for reaching high vegetation to eat, large eyes set into feathered cones in the heads of owls to gather light for night hunting.

2. Conduct a class discussion on the value of different kinds of adaptations to animals. As a part of the discussion, ask the students to identify different kinds of adaptations in humans.

3. Pool all of the students' pictures or drawings of adaptations. Categorize them into the following groups:

- protective coloration and camouflage
- body shape/form
- mouth type/feeding behavior
- reproduction/behavior
- other (one or more categories the students establish, in addition to the four above that will be needed for the rest of the activity)

4. Divide the adaptation cards into five groups of four cards each, one each of coloration, mouth body shape and reproduction.

5. Pass one complete set of cards to each group of students. There might be five groups with four to six students in each group. If the class size is larger than about 30 students, make additional sets of adaptation cards.

6. Ask the students to "fashion a fish" from the chacteristics of the cards in the set they receive. Each group should:

- create an artform that represents their fish
- name the fish
- describe and draw the habitat for their fish class

7. Ask each group to report to the rest of the about the attributes of the fish they have designed, including identifying and describing its adaptations. Ask the students to describe how this kind of fish is adapted for survival.

8. Ask the students to make inferences about the importance of adaptations in fish and other animals.

## Extensions

1. Take an adaptation card from any category and find real fish with that adaptation!

**NOTE:** A collection of books about fish is useful. Do not be as concerned about reading level as much as profuse illustrations.

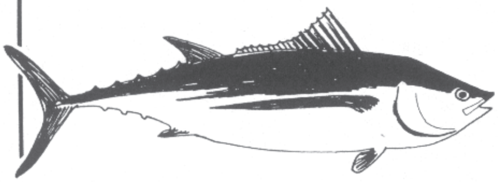
2. Look at examples of actual fish. Describe the fish's "lifestyle" and speculate on its habitat by examining its coloration, body shape and mouth.

## For Students

1. Name two fish adaptations in each of the following categories: mouth, shape, coloration, reproduction. Then describe the advantages of each of these adaptations to the survival of the fish in their habitats.

2. Invent an animal that would be adapted to live on Your school grounds. Consider mouth, shape, coloration, reproduction. food, shelter and other characteristics. Draw and describe your animal.

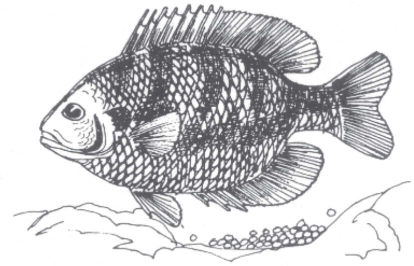
| ADAPTATION | ADVANTAGE | EXAMPLES |
|---|---|---|
| • sucker shaped mouth | • feeds on small plants/animals | • sucker, carp |
| • elongate upper jaw | • feeds on prey it looks down on | • spoonbill, sturgeon |
| • elongate lower jaw | • feeds on prey it sees above | • barracuda, snook |
| • duckbill jaws | • grasps prey | • muskellunge, pike |
| • extremely large jaws | • surrounds prey | • bass, grouper |
| **Body Shape** | | |
| • torpedo shape | • fast moving | • trout, salmon, tuna |
| • flat bellied | • bottom feeder | • catfish, sucker |
| • vertical disk | • feeds above or below | • butterfish, bluegill |
| • horizontal disk | • bottom dweller | • flounder, halibut |
| • hump backed | • stable in fast moving water | • sockeye salmon, chub, razorback |
| **Coloration** | | |
| • light colored belly | • predators have difficulty seeing it from below predators | • most minnows, perch, tuna, mackerel |
| • dark upperside | • have difficulty seeing it from above | • bluegill, crappie, barracuda, flounder |
| • vertical stripes | | • muskellunge, pickerel, bluegill |
| • horizontal stripes | • can hide in vegetation | • yellow and white bass, snook |
| • mottled coloration | • can hide in vegetation | • trout, grouper, rockbass, hogsucker |
| | • can hide in rocks and on bottom | |
| **Reproduction** | | |
| • eggs deposited in bottom | • hidden from predators | • trout, salmon, most minnows |
| • eggs deposited in nests | • protected by adults | • bass, stickleback |
| • floating eggs | • dispersed in high numbers | • striped bass |
| • eggs attached to vegetation | • stable until hatching | • perch, northern pike, carp |
| • live barriers | • high survival rate | • guppies |



Light Colored Belly (Albacore)

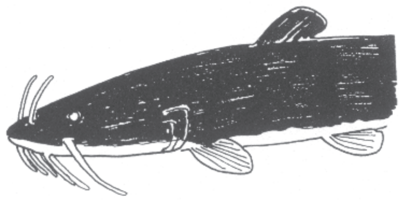
Coloration

Eggs Deposited in Nests (Blue Gill)

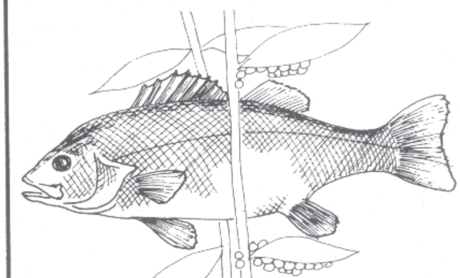


Reproduction

Dark Upperside (Catfish)

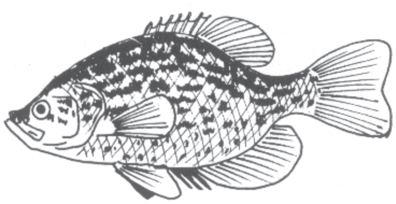


Coloration



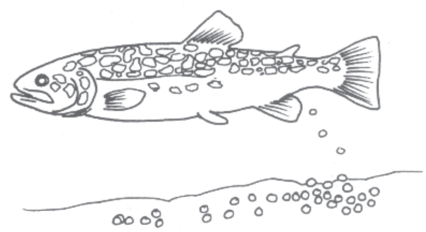
Eggs Deposited on Vegetation (Yellow Perch)

Reproduction



Mottled (Crappie)

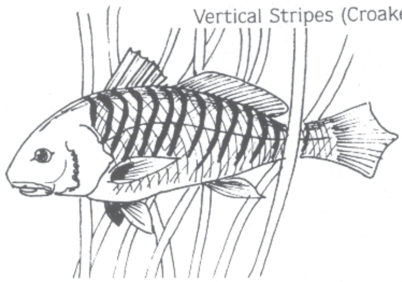
Coloration



Eggs Deposited on Bottom (Trout)

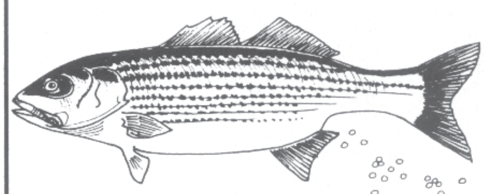
Reproduction

Vertical Stripes (Croaker)



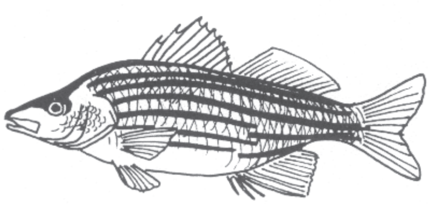
Coloration

Free Floating Eggs (Striped Bass)



Reproduction

Horizontal Stripes (Yellow Bass)

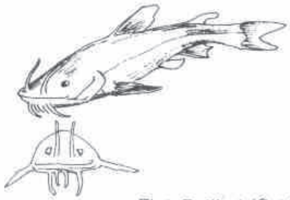


Coloration

Live Birth (Gambusia)

Reproduction

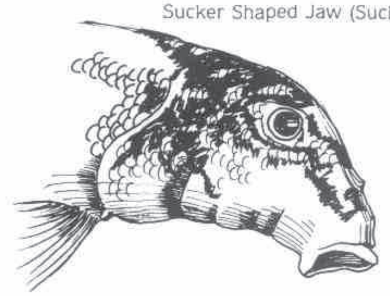
Shape



Flat Bellied (Catfish)

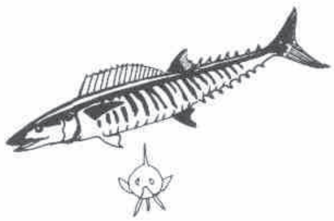
Mouth/Feeding

Sucker Shaped Jaw (Sucker)



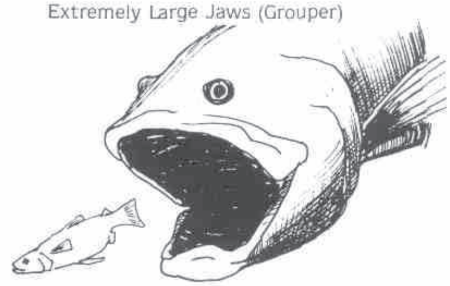
Shape

Torpedo Shape (Wahoo)



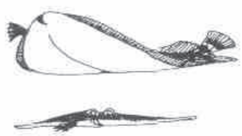
Mouth/Feeding

Extremely Large Jaws (Grouper)



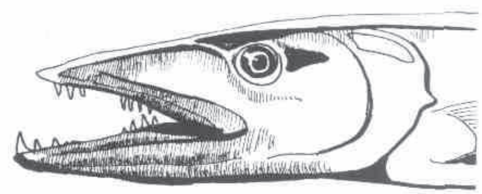
Shape

Horizontal Disc (Halibut)

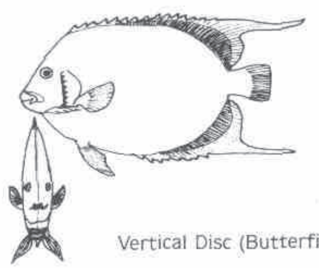


Mouth/Feeding

Elongate Lower Jaw (Barracuda)



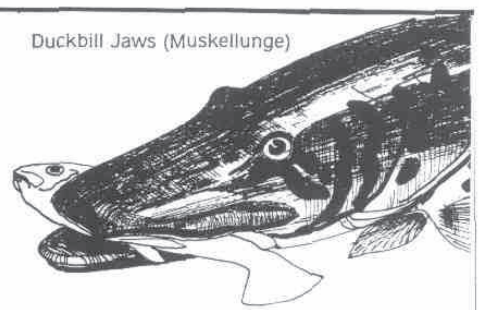
Shape



Vertical Disc (Butterfish)

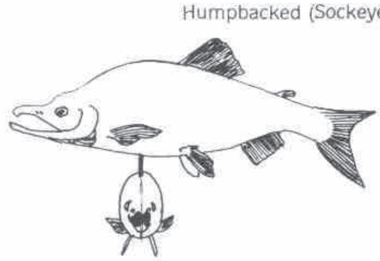
Mouth/Feeding

Duckbill Jaws (Muskellunge)



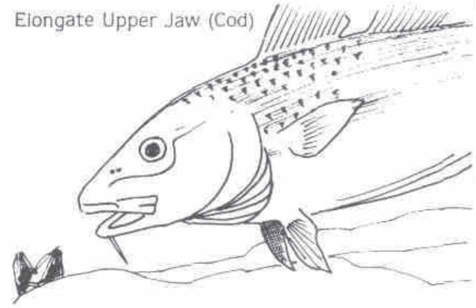
Shape

Humpbacked (Sockeye)



Mouth/Feeding

Elongate Upper Jaw (Cod)



# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 3

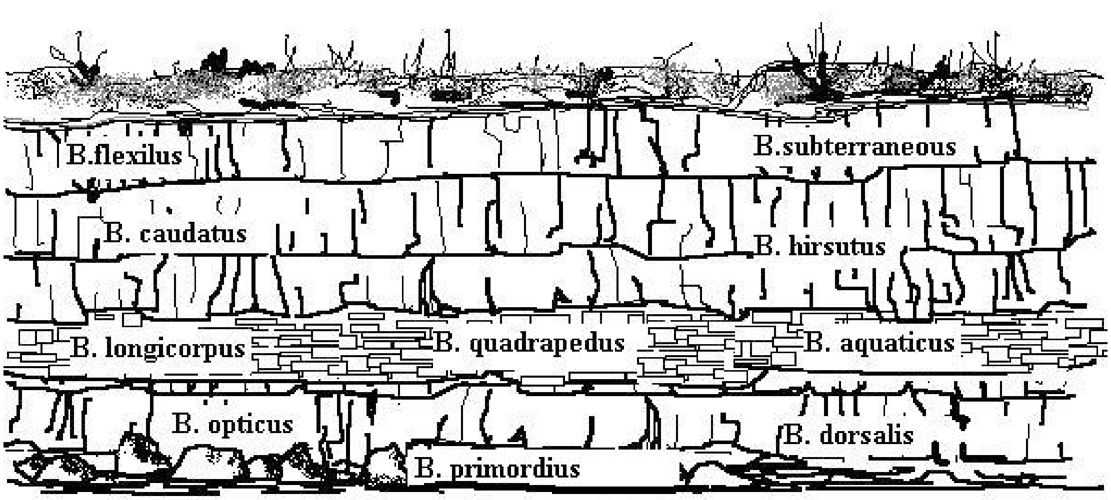
## The Evolution of Barbellus Part A

**Supplies:** Paper, scissors, rock layers containing fossils of *Barbellus* in Fig. 1, *Barbellus* drawings in Fig. 2, and tape.

**Concepts:** Using fossil evidence to construct evolutionary history, using structural characteristics to construct evolutionary history.

**Introduction:** Evolution can be defined as changes in groups of organisms over time. There are many things that can cause these changes, but one piece of evidence that shows us that organisms have changed, is the fossils we find. When living things from the past are compared to living things today, we can see that things have changed. Some fossils show us organisms that once lived on earth and are no longer found, such as the dinosaurs and trilobites.

Fossils are found in sedimentary rocks. These rocks are formed from layers of mud, sand, and other fine particles (including ash). These sediments turn to rock over millions of years and any living thing trapped in these sediments become fossilized.



# The Evolution of Barbellus Part B

**Procedure:**

1. Cut out the drawings in Fig. 2, making sure each creature's name remains with the picture.

2. Arrange the cut outs on a piece of paper to show the sequence of changes that you think might have taken place in the genus *Barbellus.*

3. Use Fig. 1 to decide on the relative ages of the species. Make sure that your arrangement agrees with the relative ages of the fossils.

4. When all in your group are satisfied with the arrangement, tape each fossil and draw the branches of your evolutionary tree.

**Discussion:**

1. Which layer (designated by layers A-F) is the oldest?

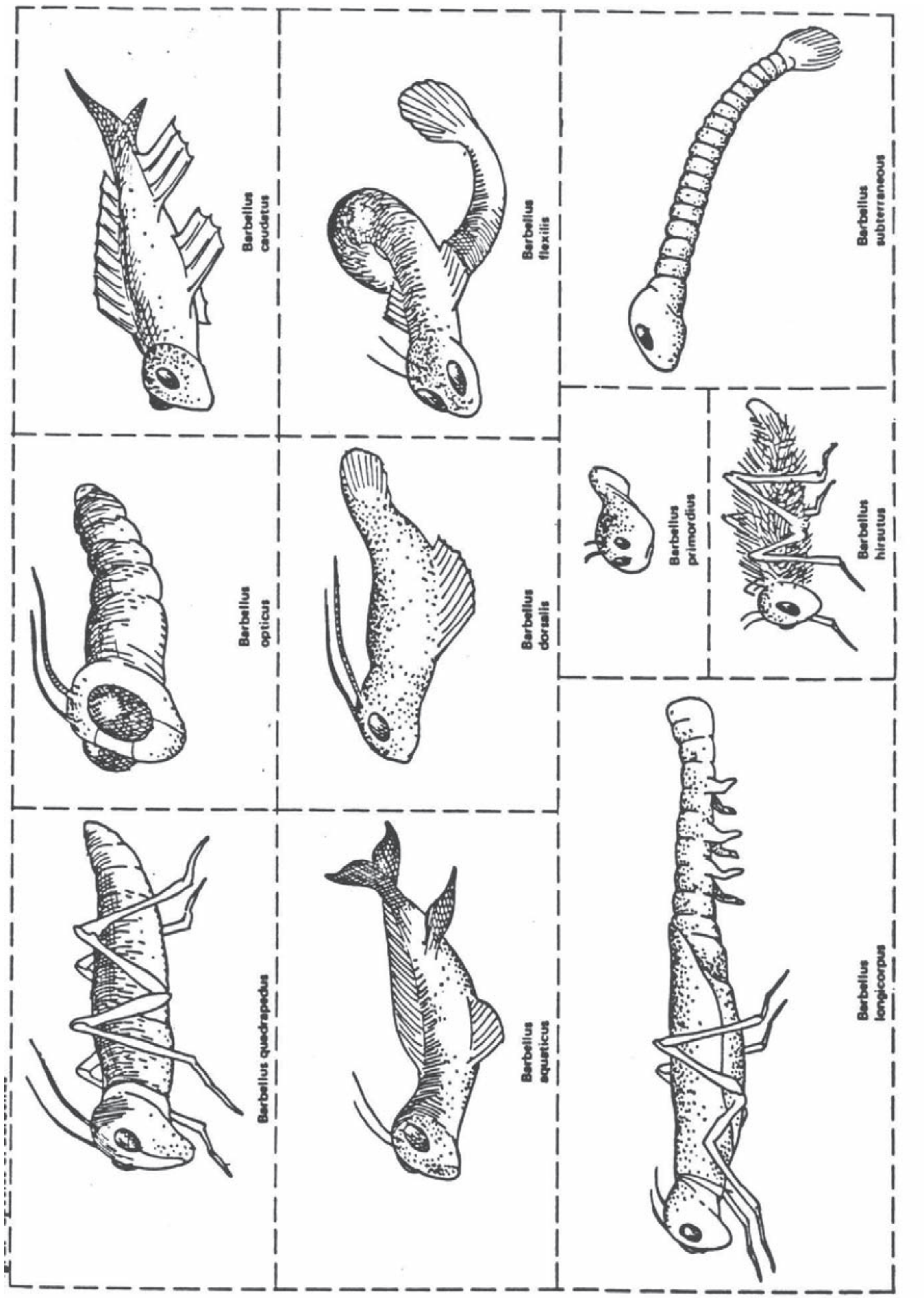
   Which fossils would be the oldest?

2. Why does the specimen *B. opticus* not appear above layer E?

3. Since specimen *B. subterraneous* does not appear until rock layer A, where did it come from?

4. Name the physical features that you used to group your organisms.

5. Write an essay that explains the evolution of *Barbellus* in terms of changes in anatomy and their causes. Their structure should show adaptations to their environment (such as fins for swimming) so be sure to include this in your explanation.


Barbellus caudatus
Barbellus flexilis
Barbellus subterraneous
Barbellus opticus
Barbellus dorsalis
Barbellus primordius
Barbellus hirsutus
Barbellus quadrapedus
Barbellus aquaticus
Barbellus longicorpus

5.Figure 2

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 5

## Caminalcules

**Supplies:** Drawings of Caminalcules (both living and fossil species), scissors, tape, 1 M X 1.5 M sheet of paper, meterstick, pencil, removable transparent tape.

**Concepts:** Using relative age of fossils to determine evolutionary history, using structural characteristics of fossils to determine evolutionary history, relating an organisms evolutionary history to current taxonomic placement.

**Introduction:** This simulation involves studying drawings of members of an imaginary phylum of animals called "Caminalcules." Students are asked to construct an evolutionary tree of these imaginary organisms based on their ages and their structural characteristics. Students should identify patterns in body plans, hypothesize the environment that these organisms lived in based on structure, and given the age of the fossils, determine their placement on an evolutionary tree.

**Procedure**
**Part A :Taxonomy of Living Caminalcules**

1. Examine the drawing of the living caminalcules in Figure 1. Start your classification by placing them in the animal kingdom. (What features indicate that the caminalcules belong in this kingdom?)

2. Your answer is based on some assumptions about the caminalcules and the functions of their structures. Further assume the following:

- The caminalcules are shown at life size.
- There is no information about their ventral surface.
- There is no information about their internal structures.
- There is no sexual differentiation in the caminalcules.
- Adult caminalcules do not vary in size.
- There is no information about their young, which may be quite different from the adults.
- There is no information about the functions of their structures.
- Each of the caminalcules is a separate species.

3. Cut out the individual caminalcules in Figure l. Look carefully at characteristics such as their appendages, shape, and color patterns. Based on your study, group similar species into genera and give each genus a name. Recall that members of a genus resemble each other more closely than they resemble members of other genera. Describe the characteristics of each genus.

4. Group the genera into one or more families. Name each family and describe its characteristics.

5. Assume the caminalcules all belong to the same order and class. Create and name a new order and class.

6. Create a new name for each species. Record each binomial name using the correct format.

7. Discuss your classification with those of other teams in the class. Try to come to a class consensus for a single classification.

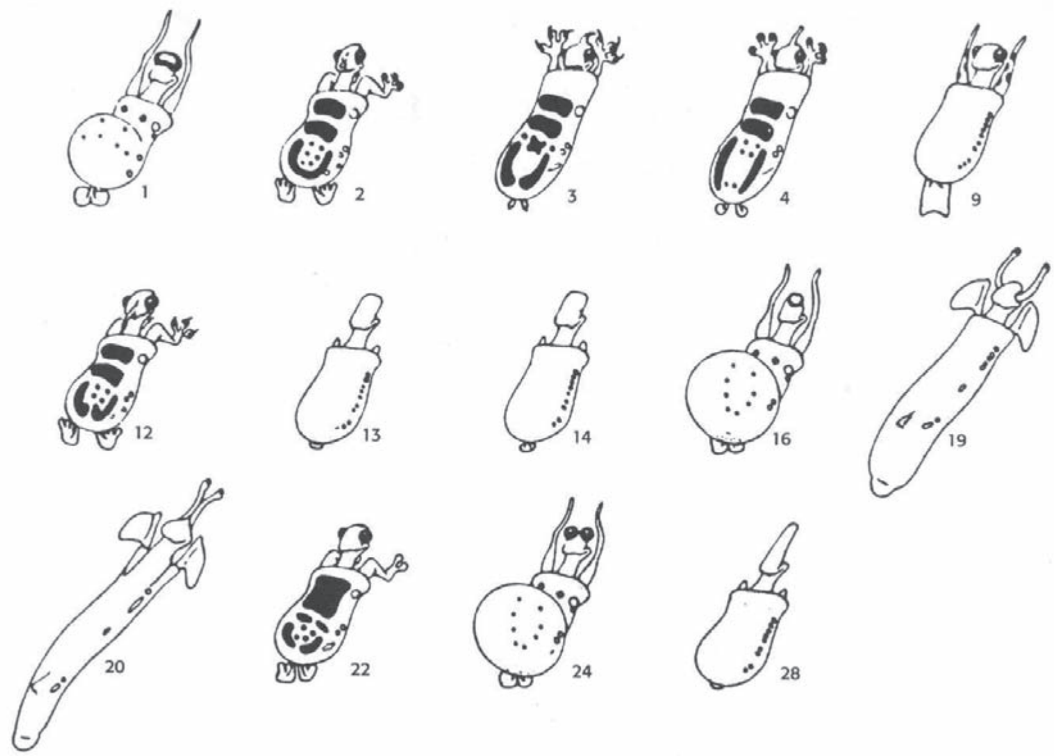



**Figure 15.1** ◆ Living caminalcules

**Living Caminalcules Fig. 1**

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 6

**Procedure: Part B**

1. Figure 2 shows fossil caminalcules. Each drawing is a separate species and each species has a number. The number in parentheses is the age of the fossil in millions of years ago. Assume the following about the fossil caminalcules

- There is as much information about each fossil caminalcules as about the living specimens.
- The exact age of each fossil is known to the closest 1 million years.

2. To determine the evolutionary relationships of the caminalcules, construct a phylogenetic tree. Use the meter stick to make 20 equally spaces horizontal lines about 5 cm apart on the large sheet of paper. Label the bottom line 19 and number upward so the top line is labeled 0. These numbers represent time intervals of one million years.

3. Cut out the fossil caminalcules in Fig. 2 and put them in piles according to their age (the number in parentheses). Beginning at the bottom of the tree, place the species on the line that match their age. Place the living caminalcule species cut out from Fig. 1 on the 0 line. Use a small piece of removable transparent tape to hold each caminalcule temporarily in place.

4. Determine the most likely relationships of the fossil caminalcules to other fossil or living caminalcules. Start your phylogenetic tree by placing the oldest fossil at the bottom of the paper on the 19 million years line. Arrange the caminalcules to reflect their relationships. Some fossils have the same species number as other fossil or living species; place these vertically above and below each other. Place the other fossil species near those that match as closely as possible newer fossil and/or living caminalcules.

5. Draw lines that indicate the relationships. A fossil species can be the ancestor or none, one or two other species at a branching point, but not of three. Sometimes there is no branching and the transition from one species to another is direct. Connect species that evolved from another species by slanted lines, not vertical ones. Use vertical lines only when the species has not evolved into a new species.

6. Because of the incomplete nature of the fossil record and different ways of interpreting the available fossils, more than one phylogenetic tree is possible. Compare your tree with that of another team. After discussing the differences and each team's rationale for its decisions, produce a revised tree.

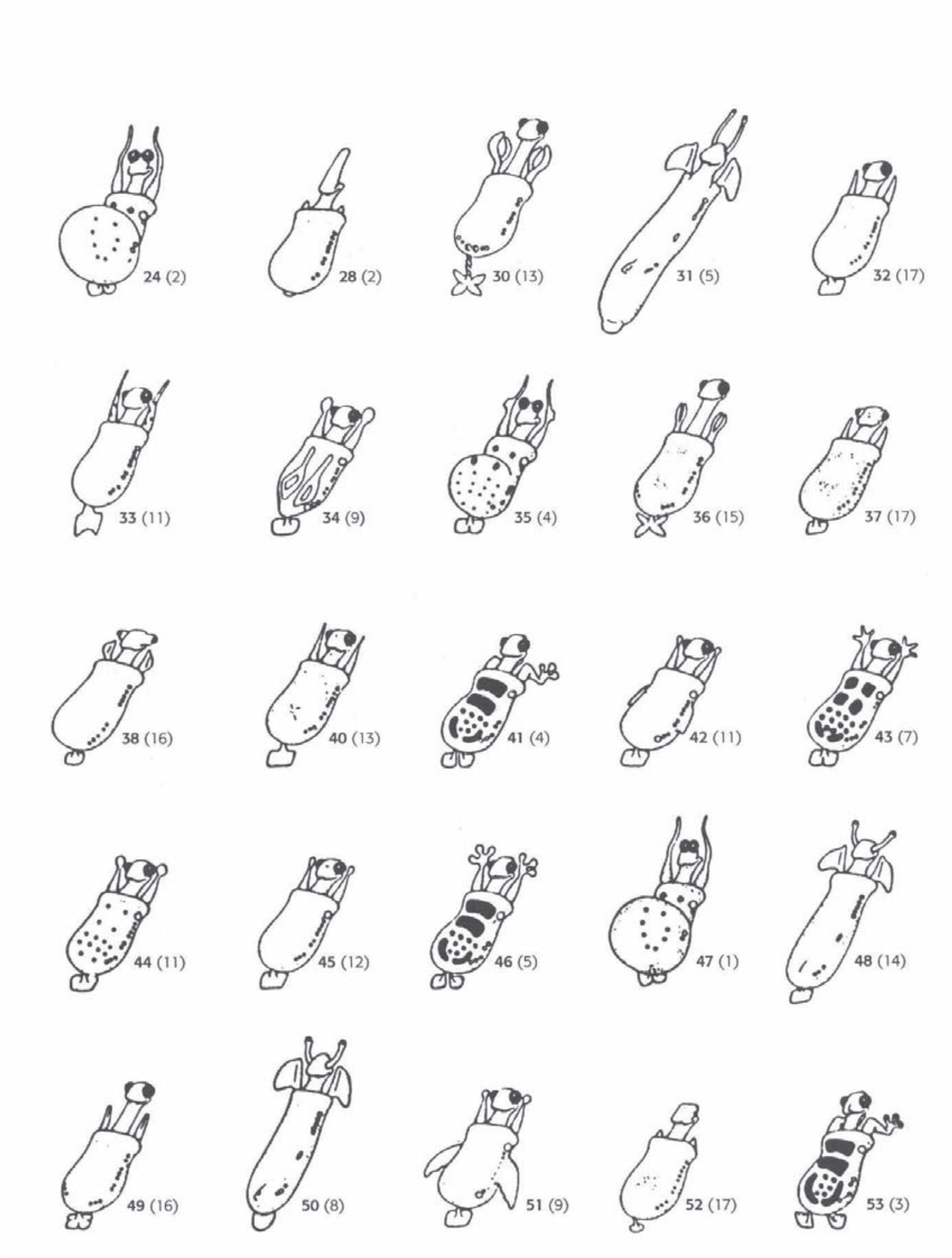



Figure 2. Fossil Caminalcule

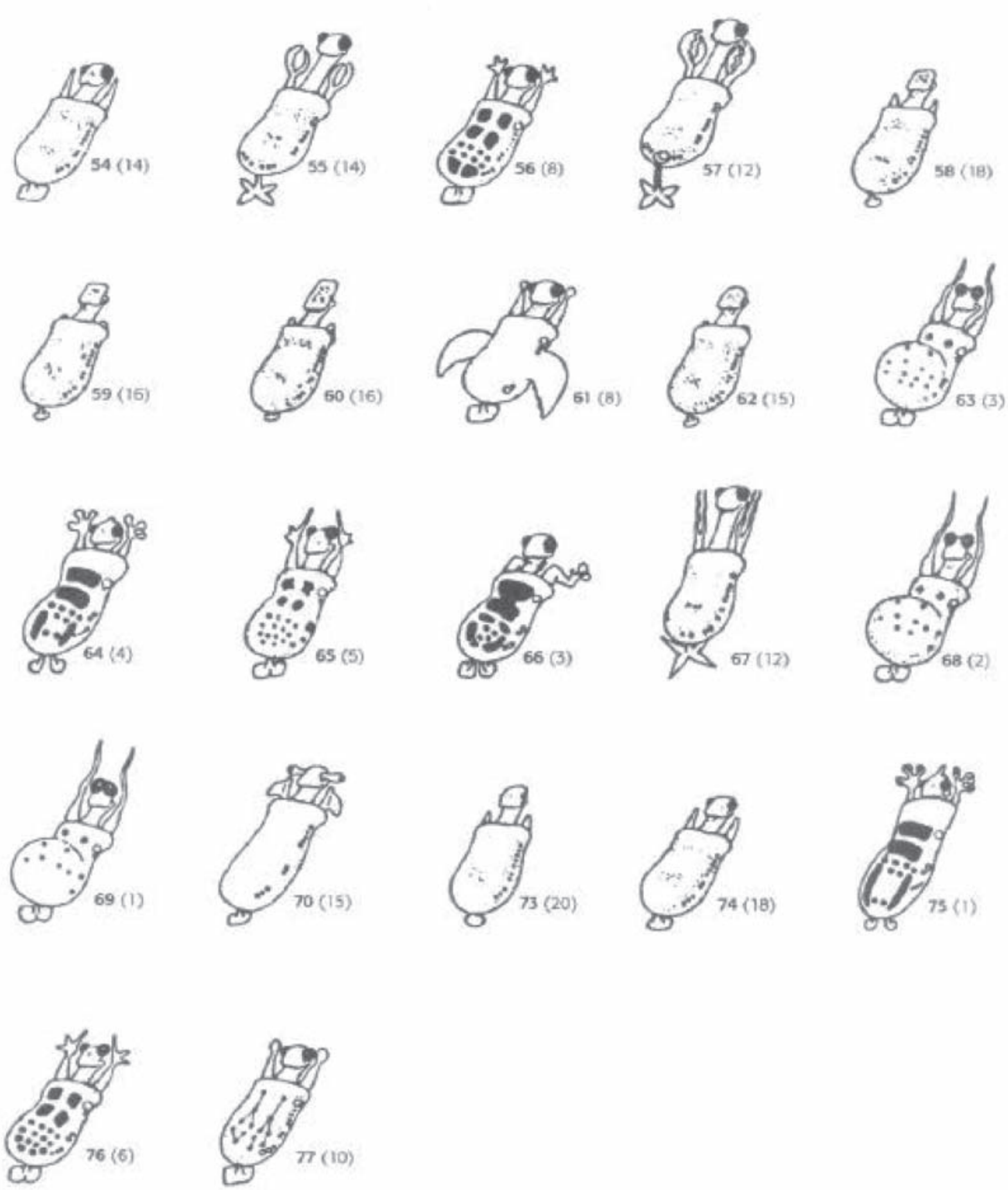
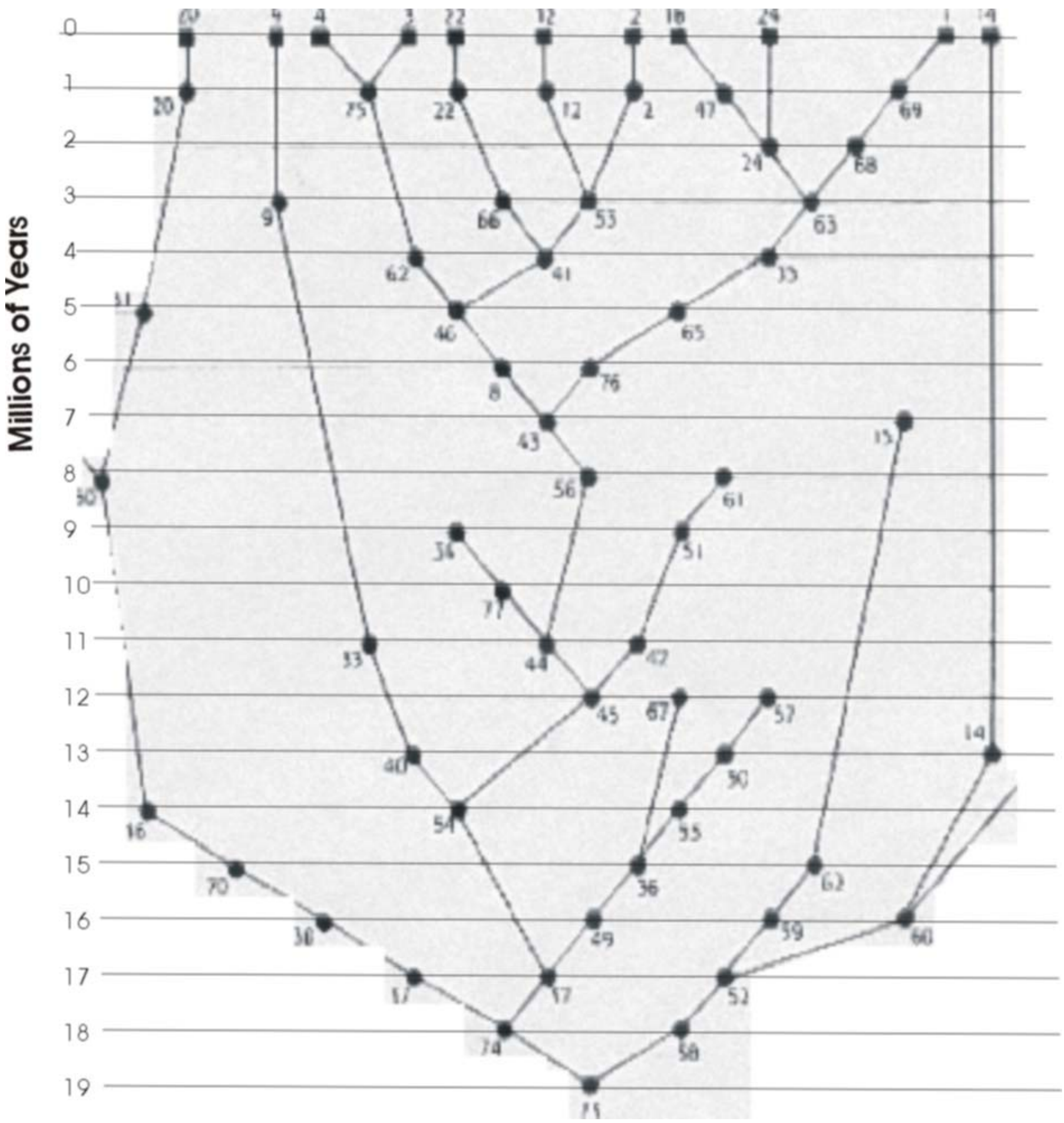



Figure 2. Fossil Caminalcule (cont.)

## Author’s Key of the Caminalcules Phylogenetic Tree




Discussion Questions

1. Answers will vary with how closely the students’ trees agree with the key. Students should compare their original classification of the living Carninalcules and see if their genera share a common ancestor. If not, they will need to rename their living species or revise their tree.

2. Students should identify which living species would need to be renamed based on their phylogenetic tree.

3. Examples of convergent evolution include the following:

- The claws of species 3 and 12 (their most recent common ancestor, species 46, did not have claws) The wings of 61 and 51 and of 19 and 20
- The single (fused) eye of species 16 and I (their shared common ancestor is species 63)
- The forelimb of species 16, 24, and I looks like that of species 9, but actually is a modified digit The head ornaments of species 12 and 3

4. Examples of vestigial structures include the following:

- The reduced digits of species 35
- The reduced feet of species 22.
- The small digit of species 66

5-6. Answers will vary, depending on whether students judge success to be long times of evolutionary stability or short times of evolutionary change. Students should justify their answers with their rationale of why one would be better than another.

7. The evolution of species 46 to 19 and 20, of 33 to 9, and of 52 to 14, 13, and 28.

8. The evolution of species 43 to 4, 3, 22, 12, 2, 16, 42, and 1. Relatively rapid environmental change might account for rapid changes in structure.

9. Lineages 13, 14, 40 and 46. Relatively unchanging environmental conditions might account for stability in structural characteristics.

**Discussion**

1. Do the evolutionary relationships shown in your phylogenetic tree require any changes in your original classification of living caminalcules? Compare the grouping on line 0 with the way you classified the caminalcules in Part A. If necessary, revise your classification so it agrees with your phylogenetic tree. All members of a genus should have the same genus name and should share a common ancestor that is not shared by members of other genera. The same rule applies to families, orders, classes, etc.

2. Does this revision make necessary a change in the genus and species names you gave some of the caminalcules? If you had to revise your phylogenetic tree and the scientific names you gave the living caminalcules, that does not necessarily mean your first tree or your original names were incorrect. Biologists continually revise their classification as they obtain more data on both living and extinct (fossil) organisms.

3. In your phylogenetic tree, the vertical distance represents time. The horizontal distance is an indication (in a general way) of how different the species are from one another. In other words, two species of the same genus should appear closer together on the tree than species of different genera. Two species that evolved from a common ancestor will be closer together on the tree than genera that did not evolve from a common ancestor. As you go back in time, the lines of relationship become closer to each other than the

4. Comparing living species also helps determine evolutionary relationships between organisms. In general, the greater the difference between the organisms, the longer ago they presumably diverged from a common ancestor. Some species, however, resemble each other because similar structures evolved independently in response to similar environments or ways of life, and not because they share a recent common ancestor. This type of evolution is called convergent evolution because unrelated species seem to converge (become more similar) in appearance. Examples of convergent evolution include the wings of bats, birds, and insects, or the streamlined shapes of whales and fishes. Thus, in classifying organisms, you must consider a number of characteristics rather than just a single one. List all the examples of convergent evolution you can identify in the fossil and living caminalcules. Look for two living species with a shared characteristic, such as similarly shaped forelirnbs, whose common ancestor did not have that characteristic.

5. Sometimes in the evolution of organisms, unused structures become reduced to the point where they are virtually useless. Examples of such vestigial structures in our species are the ear muscles and the tail bones. Compare the structures of the living caminalcules with their ancestors and list any examples of vestigial structures you can identify. These are structures that appear to be getting smaller and eventually disappear.

6. Is a successful lineage one that has branched many times and is represented by many species, or is it one that has changed the least through time? Explain your answer.

7. Are some lineages more successful than others? What are the characteristics of these lineages?

8. What evidence in caminalcule evolution indicates that evolution was relatively gradual?

9. What evidence in caminalcule evolution indicates that evolution was relatively *rapid? What might account for periods of rapid evolution?

10. What evidence in caminalcule evolution indicates long periods of stability when little evolution took place? What might account for long periods of stability?

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 7

**Making Fossil Casts**

**Supplies:**

- Molds of the fossils (available from Florissant Fossil Beds National Monument**)**
- Plastic bucket or bowl for mixing the plaster (cottage cheese or yogurt containers work well)
- Hydrocal white cement (this can be obtained from Threewit-Cooper Cement, 2900 Walnut St., Denver CO. 80205, Phone (303) 296-1666). It costs approximately $29.00 for 100 lbs. Local stucco businesses may also carry this product.
- Spoons for mixing the plaster
- Water
- Kitchen Bouquet for staining cast (Kitchen Bouquet can be purchased in the seasoning section of grocery stores)
- Optional: India ink and No. 4 Sable art brush

**Concepts:** Since it is impractical and unreasonable to study real fossils, this activity allows students to create fossil casts that have the appearance and detail of the original.

**Introduction:** This activity will allow you to make beautiful fossil casts from molds of two of the Florissant fossils. The molds are of the fossil wasp, the emblem of the monument, and the branches and cone of the fossil *Sequoia.*

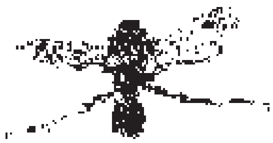
**Procedure**

1. Begin by washing the mold by putting a small amount of soap or detergent, add water, rub gently and pour the water our. Leave the mold damp but not dry. The soap will act as a wetting agent.

2. Use the plastic container to mix the plaster. In order to determine how much water you will need for the plaster, fill your latex mold with water and then pour this water into a clean bowl or bucket. Discard about 1/3 of this water**.**

3. Carefully sprinkle the plaster powder into the container of water, being careful to sift the plaster evenly all the way to the edges. This is important because the plaster must accumulate in the water evenly. You must try to avoid creating a peak in the middle of the bowl, but evenly distribute the plaster into the water. Continue this until the water will no longer absorb the plaster, leaving a little dry powder on the surface.

4. Once enough plaster has been sifted to nearly the top of the water, you can begin to stir the mixture carefully and slowly with a spoon. Keep the contained tilted at an angle to allow you to stir, keeping the spoon below the water level and keeping air bubbles to a minimum. It is important to keep air bubbles to a minimum.



5. When the mixture is ready to pour, it should have the consistency of heavy cream or cake batter.

6. Pour the mixture slowly and steadily into the mold. Roll and tip the mold during the pouring to insure that air bubbles are released. Tilt, tap gently and rotate the mold until all the trapped air bubbles have been released.

7. The cast is now left out in an open area and allowed to dry completely. When completely dryed, gently remove the cast from the mold, being careful not to break the cast. When finished, the latex mold should be completely washed and allowed to dry.

8. You can now stain the replica by creating a solution of Kitchen Bouquet and water. It takes approximately a 5:1 ratio of water to Kitchen Bouquet to get the color of the fossil shales. You can experiment with this to achieve the desired color. Dip the replica into the solution, and set out to dry.

9. You may also use a solution of Kitchen Bouquet and India ink to “paint” the fossil but this requires a very tiny art brush and very fine motor skills, which might be difficult for young children.

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 9

Making Fossil Chocolates

**Supplies:**

**Chocolate Candy Recipe**
1 cup butter
1 ½ box powdered sugar
1 can Eagle brand milk
18 oz. chocolate chips (semi-sweet, or 1/8 block almond bark=12 oz. chocolate chips)
¾ block or paraffin

Optional-
1 can coconut
2 cups nuts chopped

Melt butter, sugar, milk, chocolate and paraffin in double boiler until smooth. Add optional items just before pouring. Stir to blend only. Pour into molds and refrigerate until hard. Pull from mold and ice.

**Concepts:** Students will have an opportunity to make fossil replicas out of chocolate.

**Introduction:** Students can have fun making candy from fossil molds and creating unique gifts for members of their family and friends.

**Procedure:** Make sure that the fossil molds are clean before pouring chocolate into them. You can use a mild bleach mixture to soak them in and then be sure to rinse thoroughly before using. Once the chocolate is removed from the molds, be sure to wash them again thoroughly with a mild soap.

**(Footnotes)**
* This investigation was adapted from the BSCS Green Version, 8'b Edition, Teachers Resource Manual, Supplementary Investigation 15, pp. 151-158,1997.

# Canon Paleo Curriculum
# Unit: 3 Evolution
# Lesson Plan 10

Name ____________________
Class ____________________
Period ____________________

## How Do Fossils Show Change?

Most organisms live, die, and decompose. They leave no traces of having lived. Under certain conditions, an organism's remains or tracks may be preserved as a fossil. Fossils give clues about how an organism looked and where it lived. They are often used by scientists as evidence of change.

A fossil is any remains of a once living thing. Fossils may only be the outline of some plant, animal, or other organism that is preserved in rock. Sometimes, entire skeletons of animals that lived millions of years ago are found.

**OBJECTIVES**

In this activity, you will:

a. examine diagrams of fossil horses and present-day horses shown in their surroundings.
b. examine diagrams of the structure of the front foot of fossil horses and present-day horses.
c. note the changes in horses that have taken place over time.

**KEYWORDS**

Define the following keywords:

adaptation - a variation that helps a living organism survive

*Equus - modern horse*

fossil - remains of a once-living organism

*Hyracotherlum - fossil horse -- extinct*

natural selection - an organism's ability to adapt to its enviroment.

**MATERIALS**

metric ruler
colored pencils: red, blue, green, and yellow

**PROCEDURE**

**Part A. Change in Size With Time**

**1.** Examine the diagrams in Figure I of *Uyracothe-rium, Miohippm, Merychippm,* and *Equus.*
2. Use the diagrams to **fill** in Table 1.

Name ____________________
Class ____________________
Period ___________________

**Part B. Changes in Bone Structures With Time**

The changes in horses over the last 55 million years have been shown by studies of large numbers of fossils. The earliest kind of horse was small and had teeth that were adapted to browsing on young shoots of trees and shrubs. The present-day horse is much larger and has larger teeth that are adapted to grazing on the tough leaves of grasses. Early horses were adapted to living in wooded, swampy areas where more toes were an advantage. The single-hoofed toes of the present-day horse allow it to travel fast in the plains.

1. Examine the diagrams in Figure 2. They show fossils of the front foot bones and the teeth of horses. The foot bones at the upper right of each diagram indicate the relative bone sizes of each kind of horse.

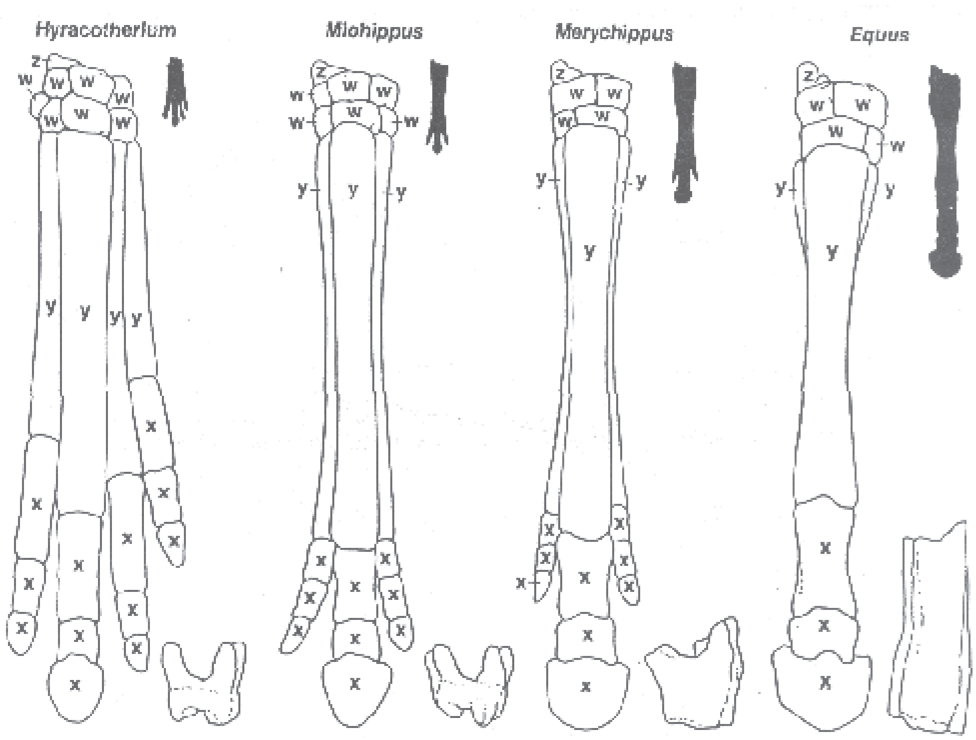



FIGURE 2. Forefoot bones and teeth of horses

2. Look for and color the following kinds of bones for each fossil horse.
   a. Color the toe bones red, these are marked for you with an x.
   b. Color the foot bones blue, these are marked with a *y.*
   c. Color the ankle bones green, these are marked with a w.
   d. Color the heel bones yellow, these are marked with a z.
3. Using the diagrams in Figure 2, make measurements to fill in Table 2.

**Table** 2. **Evolution of the Horse**

| **Kind of horse** | ***Hyracotherium*** | ***Miohippus*** | ***Metychippus*** | ***Equus*** |
|---|---|---|---|---|
| Number of toes | 4 | 3 | 3 | 1 |
| Number of toe bones | 12 | 9 | 9 | 3 |
| Number of foot bones | 4 | 3 | 3 | 3 |
| Number of ankle bones | 7 | 6 | 4 | 4 |
| Number of heel bones | 1 | 1 | 1 | 1 |
| Total number of foot bones | 24 | 19 | 17 | 11 |
| Length of foot (mm) | 9 (13) | 14(17) | 24(25) | 35(33) |
| Height of teeth (mm) | 15 | 15 | 19 | 37 |

**QUESTIONS**

1. What changes occurred in the surroundings of horses from *Hyracotherium* to *Equus?*

2. What change occurred in the shape of the horse from *Hyracotherium to Equus?*

3. What changes occurred in the size of the horse from *Hyracotherium to* Equus?

4. As the surroundings changed, what happened to the teeth of the horse?

5. Describe the overall changes in foot length, number of toes, and size of toes in the horse over time.

6. How would natural selection have caused changes in the size, feet, and teeth of the horse?

## Key for the Teacher

Name ____________________
Class ____________________
Period ____________________

**Part B. Changes in Bone Structures With Time**

The changes in horses over the last 55 million years have been shown by studies of large numbers of fossils. The earliest kind o ,f horse was small and had teeth that were adapted to browsing on young shoots of trees and shrubs. The present-day horse is much larger and has larger teeth that are adapted to grazing on the tough leaves of grasses. Early horses were adapted to living in wooded, swampy areas where more toes were an advantage. The single-hoofed toes of the present-day horse allow it to travel fast in the plains.

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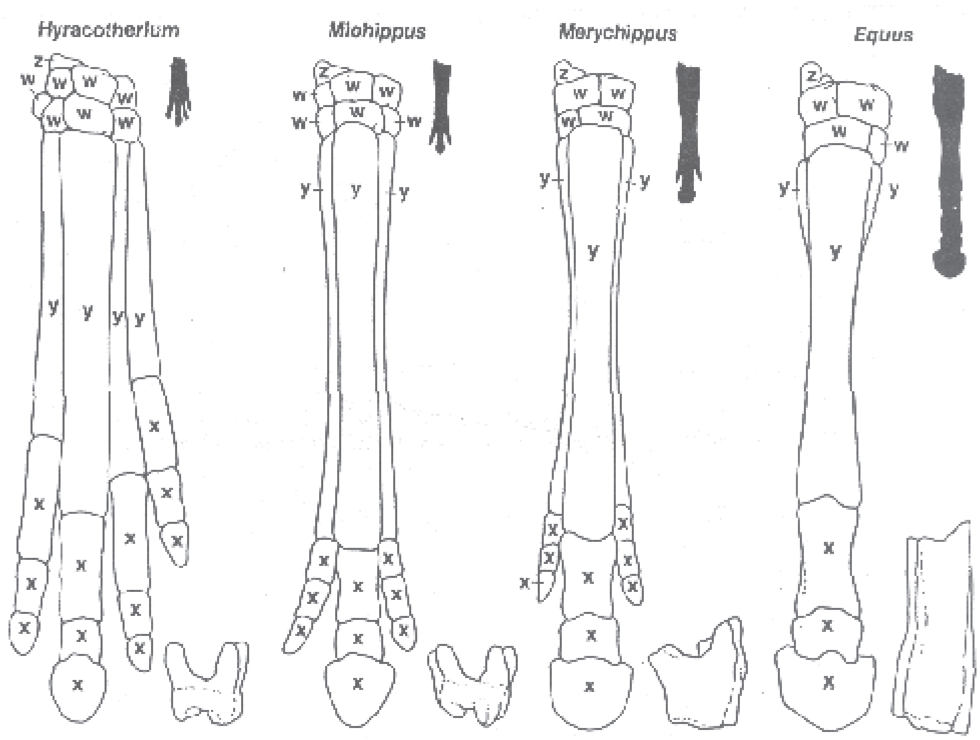


**FIGURE 2.** Forefoot bones and teeth of horses

## Key for the Teacher

2. Look for and color the following kinds of bones for each fossil horse.
   a. Color the toe bones red, these are marked for you with an x.
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**Table** 2. **Evolution of the Horse**

| **Kind of horse** | ***Hyracotherium*** | ***Miohippus*** | ***Metychippus*** | ***Equus*** |
|---|---|---|---|---|
| Number of toes | | | | |
| Number of toe bones | | | | |
| Number of foot bones | | | | |
| Number of ankle bones | | | | |
| Number of heel bones | | | | |
| Total number of foot bones | | | | |
| Length of foot (measure inset diagrams) (mm) | | | | |
| Height of teeth (mm) | | | | |

**QUESTIONS**

1. What changes occurred in the surroundings of horses from *Hyracotherium* to *Equus?*

2. What change occurred in the shape of the horse from *Hyracotherium to Equus?*

3. What changes occurred in the size of the horse from *Hyracotherium to* Equus?

4. As the surroundings changed, what happened to the teeth of the horse?

5. Describe the overall changes in foot length, number of toes, and size of toes in the horse over time.

6. How would natural selection have caused changes in the size, feet, and teeth of the horse?

**Table 1. Evolution in the Horse**

| Horse | Miohippus | Merychippus | Merychippus | Equus |
|---|---|---|---|---|
| Size | 38CM | 65CM | 100CM | 140CM |
| Type of surroundings | Swamp dense forest | dry with trees and dhrubs | grasslands | grasslands |

**QUESTIONS**

1. What changes occurred in the surroundings of horses from *Hyracotherium* to *Equus?*

   the land became drieer forest and heavy vegetation replaced by grasses and plains

2. What change occurred in the shape of the horse from *Hyracotherium to Equus?*

   early horses were small and had curved backs

   todays horse are much larger with straight backs

3. What changes occurred in the size of the horse from *Hyracotherium to* Equus?

   the height increased form 38 cm to 140cm

4. As the surroundings changed, what happened to the teeth of the horse?

   the teeth become larger and flatter as adaptation to grazing

5. Describe the overall changes in foot length, number of toes, and size of toes in the horse over time.

   the foot increased in length, ankle bones decreased, Number of toes decreased, sign of side toes became shorter than the central toe which became larger

6. How would natural selection have caused changes in the size, feet, and teeth of the horse?

   adaptation to a change in the environment would have given an advantage to horses that had them these horses would have had a greater chance of surviving that horses not adapted.

## UNIT THREE EXAM

**True and False.  Put a T Or F by the statements.**

_____1. Living things adapt to surrounding have the best chance of surviving.

_____2.  Prehistoric leaves and animals are fossils.

_____3.  Fossils provide evidence for evolution.

_____4.  Life forms that come into existence are said to be extinct.

_____5.  Sedimentary rock is layered.

_____6.  Evolution depends on desirable traits being passed on to offspring.

**Multiple Choice. Put the letter on the line that best completes the sentence.**

_____7.  A change in the hereditary features of a group of organisms over time is called:
a. mutation    b. variation    c. natural selection   d.  evolution

_____8.  Rocks that form in layers of mud, sand, and other fine particles are____ rocks.
a. sedimentary         b. igneous     c. metamorphic        d.  clastic

_____9.  The structure of a bird's toes changing over time is an example of:
a. selection   b. adaptation           c. survival     d. development

_____10.  The most important advantage an adaptation gives a living thin is to help it to survive in order that it may:
a. kill   b. reproduce   c.  an adaptation     d. selection

_____11.  A trait that makes an individual different from others in its species is:
a. a variation   b.  competition       c.  adaptation          d. selection

_____12.  One kind of evidence that life existed in the past is called a:
a:  mutation   b. fossil         c. variation    d. selection

**Match the phrases with the letter of the correct word.  Write your choice on the line to the left.**
**A.  Adaptation                    B.  Competition                C.  Natural Selection**

_____13.  Two robins will struggle over a worm.

_____14. The long beak of a hummingbird is used to sip nectar.

_____15. The mud-colored frog will survive and reproduce in a muddy pond.

_____16. The hollow bones of a bird helps it fly.

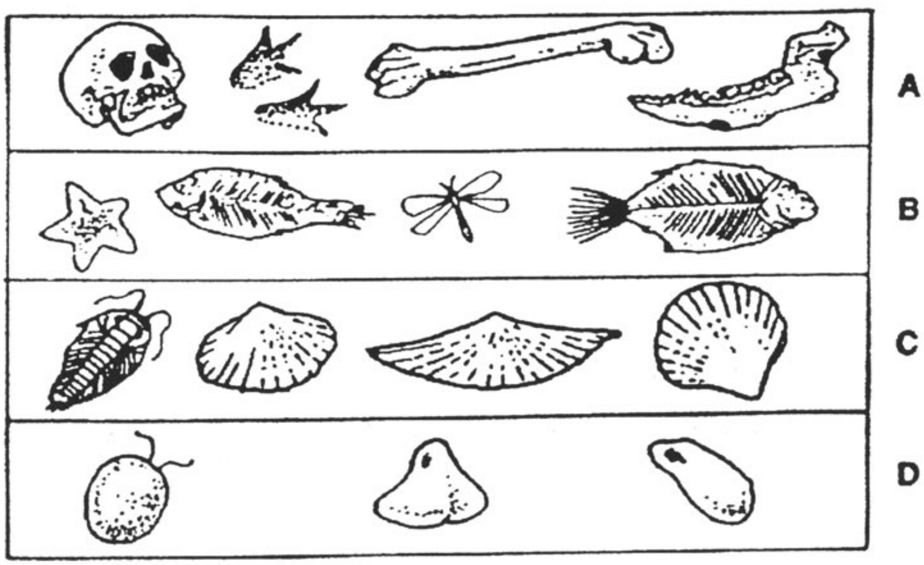
_____17. Oak seedlings are rivals for sunlight.

_____18. The hard, cone-shaped beak of the cardinal is used for eating seeds.

_____19. The white rabbit will not survive in a forest environment.

_____20. The flippers of a dolphin are used for swimming.

**The diagram shows rock layers with fossils as they might be found. Write the letter on the line. Two letters may be used, either is correct.**




_____21. The layer that has the simplest life forms.

_____22. The layer that has more life forms still alive today.

_____23. The oldest layer.

_____24. The layer with most complex life forms.

_____25. The layer revealing live no longer dependant on living in the ocean.

## UNIT THREE EXAM – TEACHER'S KEY

**True and False. Put a T Or F by the statements.**

__T__1. Living things adapt to surrounding have the best chance of surviving.

__T__2. Prehistoric leaves and animals are fossils.

__T__3. Fossils provide evidence for evolution.

__F__4. Life forms that come into existence are said to be extinct.

__T__5. Sedimentary rock is layered.

__T__6. Evolution depends on desirable traits being passed on to offspring.

**Multiple Choice. Put the letter on the line that best completes the sentence.**
**Two letters may be used, either or both are correct.**

_A,D_7. A change in the hereditary features of a group of organisms over time is called:
a. mutation b. variation c. natural selection d. evolution

__A__8. Rocks that form in layers of mud, sand, and other fine particles are____ rocks.
a. sedimentary b. igneous c. metamorphic d. clastic

__B__9. The structure of a bird's toes changes over time is an example of:
a. selection b. adaptation c. survival d. development

__B__10. The most important advantage an adaptation gives an organism is to help it to survive in order that it may:
a. kill b. reproduce c. an adaptation d. selection

__A__11. A trait that makes an individual different from others in its species is:
a. a variation b. competition c. adaptation d. selection

__B__12. One kind of evidence that life existed in the past is called a:
a: mutation b. fossil c. variation d. selection

**Match the phrases with the letter of the correct word.  Write your choice on the line to the left.**

**A.  Adaptation          B.  Competition          C.  Natural Selection**

__B__13.  Two robins will struggle over a worm.

__A__14.  The long beak of a hummingbird is used to sip nectar.

__C__15.  The mud-colored frog will survive and reproduce in a muddy pond.

__A__16.  The hollow bones of a bird helps it fly.

__B__17.  Oak seedlings are rivals for sunlight.

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**The diagram shows rock layers with fossils as they might be found. Write the letter on the line.  Two letters may be used, either or both are correct.**

__D__21.  The layer that has the simplest life forms.

__A__22.  The layer that has more life forms still alive today.

__D__23.  The oldest layer.

__A__24.  The layer with most complex life forms.

_A,B_25.  The layer showing evidence that life is no longer dependant on living in the ocean.