Chapter 9

The Use of Fossils in Interpreting Past Environments

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Contents

Introduction

Biological science textbooks introduce such concepts as evolution, extinction, and paleoecology, but it is difficult to appreciate the importance and origin of these terms without some sort of interactive experience. Students need to realize that the organisms living today are only a small percentage of the total diversity of life that have inhabited our planet during the past 4.5 billion years; the oldest fossils being approximately 3.5 billion years old. As paleontology (the study of past life) is an integral mix of both geology and biology, a knowledge of modern organisms provides the basis for the understanding of past life. Many types of animals and plants have existed previously and many have gone extinct on our planet. Although evolutionary processes are difficult to observe, extinction can be seen at an alarming rate today.

This exercise is not a step by step approach to one particular problem, but rather is a method by which certain concepts can be presented to the students. As the material to be taught and specimen availability will vary, the information that follows should be used to tailor an exercise to each instructor's class. Therefore, the actual exercise should be designed by the individual instructor.

Rocks, Fossils, and Past Environments

Currently, there are many environments on our planet that sustain life. The most successful organisms are those that are adapted for living in a particular environment. Various specializations of body form and morphology relate directly to the environment that a species occupies. By knowing the successful adaptations of organisms today (i.e., functional morphology), we can better understand past life and environments. Thus, fossils provide us with a "picture" of not only past animals and plants, but also the environment they occupied. The objective of this exercise is to make the animals and plants of the past more that just static objects in a museum or some other collection, but rather living, breathing, interacting organisms.

Reconstructions of past environments are important to understand questions interrelated with paleoecosystems. Information on physiology, diet, adaptations, behavior, evolution, and extinction of past life forms hinges upon a clear understanding of paleoecology. To make these determinations, paleontologists utilize fossils and certain rocks to reconstruct ancient worlds. Interaction with fossils and rocks is integral to a clear understanding of paleontological principles by students in the sciences.

The concept of uniformitarianism is commonly used to understand past life and environments. This principle states that the present is the key to the past. For example, morphological adaptations appear to have remained somewhat constant throughout geologic time. In other words, if you are going to live like a fish you will probably look like a fish. A comparison of extant and extinct forms that occupy an active, fully aquatic existence supports this idea (e.g., sharks, dolphins, ichthyosaurs).

Fossils are the key to our understanding of past life. Fossils include such things as petrified and unpetrified hard parts (e.g., bones, teeth, exoskeletons, wood), trace fossils (e.g., tracks, burrows, trails), and naturally occurring casts, molds, and impressions. Basically, any evidence that an organism was present is considered to be a fossil. Therefore, a good definition for a fossil is any naturally occurring evidence of past life.

In addition to fossils, the rocks that contain fossils can also provide information on past environments, as well as geologic time. Most fossils are found in sedimentary rocks. Sedimentary rocks are perhaps the easiest of the three rock types (sedimentary, igneous, and metamorphic) to understand because their parent material (i.e., sediment) is recognizable to everyone. Mud, silt, sand, and gravel are all examples of sediments. The location where these sediments are naturally found is considered to be the depositional environment of the sediments. This location is also the depositional environment of any organic material (e.g., bone or wood) that might be buried within the sediments. A visit to a beach or river today will illustrate the concept of depositional environments. At these locations many layers of sand or mud can be found. Within these layers will be the remains of plants or animals. If this sediment and the enclosed organic material is lithified into rock, then one might find a sandstone or shale containing plant impressions or petrified bone in the distant future. Conversely, if a rock is found today containing the remains of some organism, the ancient depositional environment can be determined. In addition, sedimentary structures, such as ripple marks or mud cracks, can provide information on the depositional environment. These are also commonly preserved in the geologic record.

Geological time is also derived from rocks. Although relatively recent fossils (within the past 70,000 years) can be dated via C^{14} dating (which dates the age of the organisms based upon the ratio of stable to unstable carbon isotopes found within the tissues of plant or animal remains), organisms that are found in older rocks are dated based upon the age of the rock itself. Similar radioactive decay methods to C^{14} dating are utilized, but the elements dealt with are found within the rocks that either contain the fossils or are stratigraphically above or below those layers with the fossils. The names for the various geologic time intervals (i.e., epochs, eras, periods) relate to the fossils that are enclosed within the rocks (see Table 9.1). For example, the Paleozoic, Mesozoic, and Cenozoic eras mean “early life,” “middle life,” and “recent life,” respectively. Dating of the rock units based upon the fossils they contain or their stratigraphic position is referred to as relative age dating. This is different from absolute age dating in which an actual number of years is assigned to the rocks. Radioactive decay methods (e.g., C^{14} dating) are used for absolute age dating.

Museums and Collections

One way to utilize fossils to illustrate biological principles is by using local museum exhibits. At the end of this chapter are some excerpts taken from a lesson developed for the General Biology classes at the University of Wyoming. The specimens are currently on display at the U.W. Geological Museum in Laramie. Note that most of the questions are discussion-oriented and deal with biological concepts that the students must integrate into their answers. In some instances the questions relate to issues being debated by scientists today (e.g., extinction). The complete exercise, which usually takes the students about 1 hour, is meant to be followed up with a discussion session and was designed to complement their textbook. Many cities have museums with paleontological specimens. Even many non-natural history museums have fossils on display. Sometimes private collections exist that can also be used as teaching tools.

Table 9.1. Geological timetable. [From Breithaupt, B. H. 1990. Paleontology. Pages 189–203, *in* General biology laboratory manual: Principles (J. M. Beiswenger and R. M. Kitchin, Editors). Burgess Press, Minneapolis, 229 pages.]

ERA	PERIOD	EPOCH	Approximate Beginning (millions of years before present)	Approximate Duration (millions of years)	ANIMALS	PLANTS
CENOZOIC	Quaternary	Recent (Holocene)	0.01	0.01	Modern humans	Decline of woody plants; rise of herbaceous plants.
		Pleistocene	2	2	Ice Age. Evolution of humans. Evolution and extinction of giant mammals. Horses became extinct in North America	Extinction of many species.
	Tertiary	Pliocene	5	3	Early hominids.	Rise of modern floras. Forests decline.
		Miocene	25	20	First deer.	Grasslands spread.
		Oligocene	40	15	First rhinos and anthropoids.	Monocots common.
		Eocene	55	15	First artiodactyls and perissodactyls. First horses, whales, elephants, camels, cats and dogs.	First grasses
		Paleocene	65	10	Most modern orders of mammals appear.	Rise of monocots; dicots common.
MIDDLE AND LATE MESOZOIC	Cretaceous		140	75	First marsupials and placentals. First snakes, primates, and modern birds. Some orders of modern mammals present. Mosaurs present. Extinction of dinosaurs, large marine reptiles and many invertebrates at end of the period.	Angiosperms spread. Gymnosperms decline.
	Jurassic		195	60	First frogs, salamanders, birds, and flying reptiles (pterosaurs). Dinosaurs dominant.	First sequoias. Cycads and conifers common; probable origin of angiosperms.

ERA	PERIOD	EPOCH	Approximate Beginning (millions of years before present)	Approximate Duration (millions of years)	ANIMALS	PLANTS
EARLY MESOZOIC	Triassic		230	50	First dinosaurs, mammals, ichthyosaurs, turtles, lizards, and crocodiles. Reptiles replace amphibians as the dominant land animal. Last of the giant amphibians.	Extinction of seed ferns; gymnosperms dominant.
PALEOZOIC	Permian		280	50	First mammal-like reptiles. Reptiles diversify. Major extinction of invertebrates at end of the period. Giant amphibians.	Decline of lycopods and horsetails; seed ferns and gymnosperms.
	Carboniferous		345	65	First reptiles and flying insects. Amphibians dominant, insects common	First conifers, ferns and Ginkgos. Tropical coal forests (lycopods & horsetails dominant).
	Devonian		395	50	First ammonites, insect-like arthropods, sharks, and land vertebrates. (amphibians). "Age of fish."	First seed plants (gymnosperms) First forests.
	Silurian		435	40	First air breathing arthropods. Abundant armored fish, first fish with jaws	First land vegetation
	Ordovician		500	65	First bryozoans and vertebrates (jawless fishes). Invertebrates dominate the seas.	Probable origin of land plants.
	Cambrian		570	70	First corals, gastropods, plecypods and cephalopods. Trilobites and brachiopods dominant. All major invertebrate phyla present.	Marine algae diversify.
PRE-CAMBRIAN			From origin of earth 4.5-5.0 billion years ago.		Fossil coelenterates, annelids, and "worms". Possible arthropods and mollusks.	Primitive aquatic plants (algae) and fungi; bacteria.

Unfortunately, not all cities have museums or private collections containing paleontological specimens. In these cases it is necessary to create one's own “museum” in the classroom. Once specimens are obtained, an exercise similar to that created for the U.W. Geological Museum can be made. A classroom “museum” has the additional advantage of allowing hands-on time with the specimens. Specimens for such purposes can be obtained from scientific supply companies, local collectors, nearby museums, or class field trips. When purchasing specimens, plaster or fiberglass casts of fossils are strongly encouraged. The reason for this is that hands-on activities will lead to attrition and the eventual destruction of the specimens. In addition, fossils are valuable, nonrenewable geological resources. Not all specimens can be easily replaced. This is the case with vertebrate fossils which are extremely rare and generally should not be sold commercially. Although sometimes rare and often unusual, because of their abundance and good preservational quality, invertebrate and plant fossils are generally not considered as unique. Thus, because of the quality of casts today, the lower cost compared to actual fossils, high durability, and ease of replacement, casts should be used as much as possible in the classroom setting. Many new museum exhibits (e.g., Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta) consist almost entirely of casts. In most museum exhibits, it is essentially impossible to distinguish between the real fossils and the casts.

If actual fossils are to be used in classroom settings, several possibilities exist to obtain such material. Sometimes museums have parts of their collections that, because of the quality of preservation or lack of associated data (e.g., locality information), may be given to educators for classroom use. It is encouraged that you contact your local or state museum that has a paleontology collection to not only develop a paleontological field trip as discussed below, but also to possibly obtain specimens for your classroom. Many cities also have active rock, mineral, and fossil collectors—often they are part of a local rock and mineral club. These amateur collectors and their hobby organizations may also be able to provide specimens for classroom use. Local rock and mineral shops should also be approached for the donation of specimens for the classroom. You will find that most individuals are supportive of educational activities. Some scientific supply houses also carry specimens (see Appendix A).

Specimens can also be obtained through a field trip, where you and your students find fossils. Most areas have some type of fossils found nearby. Contact your local museum, university, or rock and mineral club as where to go. Fossils that are obtained in this manner allow the students to not only identify the material (based upon their current knowledge of biology), but also to reconstruct the ancient environment of the area. This allows students to make a direct comparison of how evolution (evolution can be defined as simply meaning “change through time”) and extinction have taken place at a particular location. Please be knowledgeable and courteous of land ownership and collecting regulations. Please be careful when removing fossils from the ground. Contact a qualified paleontologist if you believe that you have uncovered something unique. Most libraries can provide you with excellent references for fossil identification (see Appendix B).

Making Molds and Casts

Rather than purchasing specimens, it is possible for classes to make their own casts of fossil specimens if originals can be obtained for a short period of time. This can be done with a fairly simple list of equipment.

Quick-setting (within minutes) dental molding (e.g., Jeltrate) and casting (e.g., dental stone) material is suggested, although a slower (approximately 1 day) curing material (silicone or latex rubber and standard plaster) may also be used. Usually, the slower types of molding compounds are more durable. Your local dentist will be able to provide information on where dental supplies can be obtained in your area. See Appendix C for some supply companies. The following are instructions for making your own casts (see Figure 9.1).

1. Obtain an original fossil.
2. Make sure that the specimen is clean. If it is a delicate specimen, protect it with some type of preservative (e.g., thinned shellac or Duco cement) or do not cast it.
3. Make a clay base for the specimen.
4. Press the specimen into the clay (Figure 9.1A). Be careful not to break the specimen.
5. Using clay, cover all overhangs that are not critical parts of the morphology of the specimen (Figure 9.1B).
6. Roll out some clay to form a wall. Press the clay flat, then cut straight edges forming a wall of appropriate height (Figure 9.1C).
7. Place the wall around the clay base (Figure 9.1D). Leave at least 1/4" clearance around the specimen. Close the wall off.
8. Form a "moat" around the specimen in the clay (Figure 9.1E).

   Note: Instead of using clay a small paper or plastic container can also be used for the borders of the mold (Figure 9.1F). The bottom of a paper cup can also be used successfully.
9. Mix molding compound (e.g., dental rubber). Stir it thoroughly, but slowly to avoid forming air bubbles. The material should be viscous but pourable.
10. Spoon in small amounts of the molding compound along the inside edges of the clay wall so that the rubber slowly engulfs the specimen.
11. Proceed in this way until the specimen is covered, then add one final glob of molding compound.
12. After the material has cured remove the mold from the clay and carefully remove the specimen from the mold.
13. Mix casting material (e.g., dental plaster). Stir thoroughly, again try to avoid air bubbles.
14. Carefully fill the mold with the casting material.
15. After the material has cured, carefully remove the cast from the mold (numerous casts can usually be made from each mold). Some molds (e.g., those made of Jeltrate) will have to be stored in moist, air-tight containers to maintain flexibility.
16. Color the cast as desired using paints, crayons, markers, colored pencils, etc.

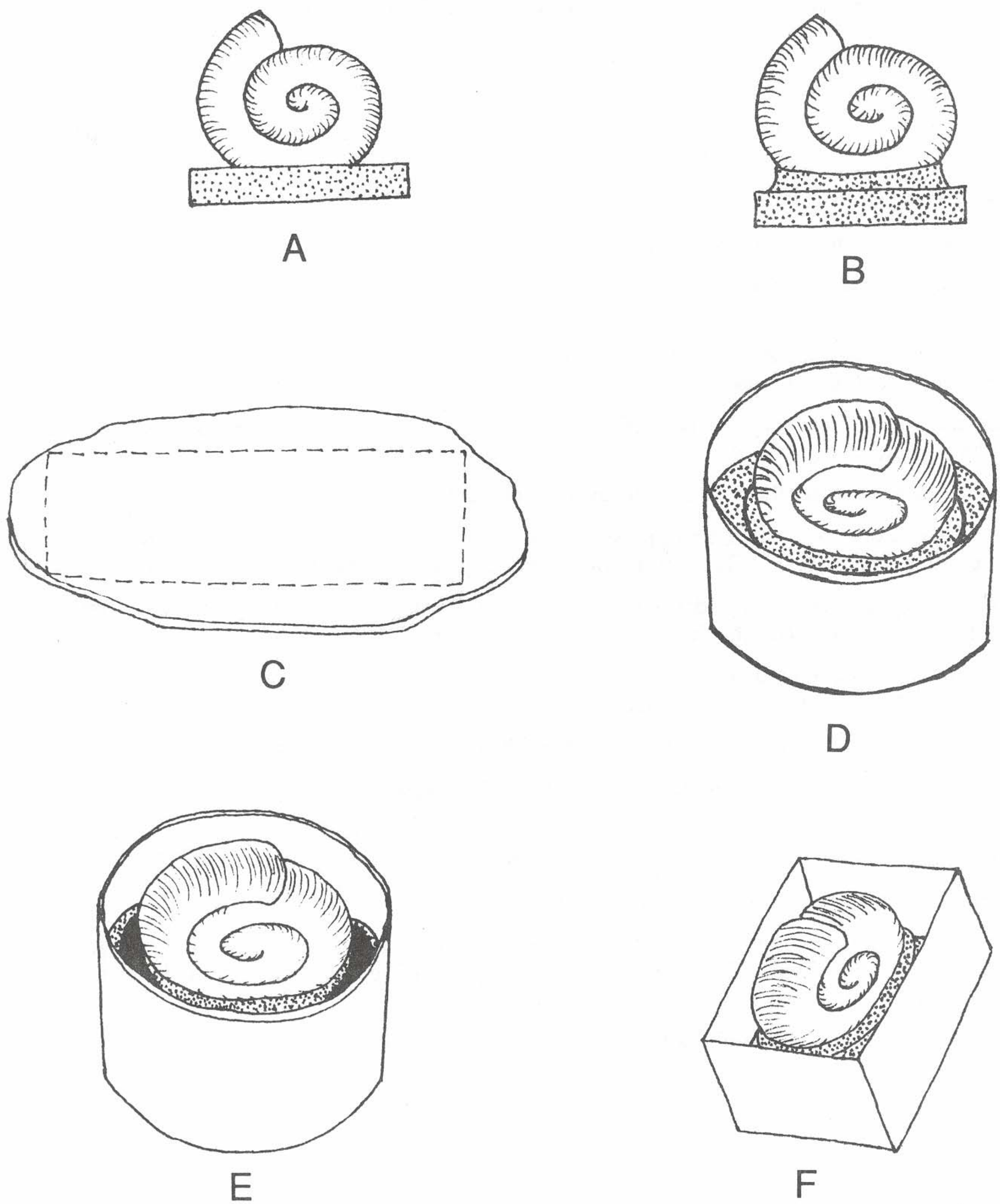

Figure 9.1. Steps for making fossil casts. See text for details.

Information from the Specimens

Once specimens are obtained or casts are made, the following exercise can be undertaken by the students:

1. Identify the specimen(s) based upon the students basic knowledge of biology. Have them compare the specimen(s) with recent material (e.g., hard parts of extant organisms) in the laboratory or in collections.
2. Interpret the past environment of the fossil, utilize all available evidence (paleontological, geological, and biological).
3. Reconstruct the paleoenvironment. This is best done with multiple fossils found in association.
4. Compare this ancient environment to that of where the fossil was found.
5. If the environment is different, provide a possible explanation of why the environment has changed over time.
6. How have the organisms in these environment morphologically changed through time?
7. Why have they changed or not changed?
8. What morphological adaptations appear to be consistent through time?
9. Teeth are one of the best indicators of past diets in vertebrate animals. If one of the study specimens has a tooth or is a tooth, what was the diet of the animal? What animals have these types of teeth today? What animal is the fossil from? Compare with modern forms. Do the extant relatives of this fossil organism have teeth like this today? If not, why?
10. Evidence of paleoactivities and paleobehaviors can sometimes be seen in the fossil record (e.g., tracks, trails, aggregations, and inter- and intraspecific interactions). From the specimens studied, can you see any indication of ancient behaviors or activities?

Many other kinds of information can be illustrated. See Appendix D for examples from the exercise presently being used in the General Biology classes at the University of Wyoming.

Summary

A comparison of the remains of fossilized and recent organisms can provide important information about ancient environments, as well as various principles in biology. This exercise provides information on (1) how paleoenvironments are determined, (2) how to obtain specimens for classroom use, and (3) how to utilize these specimens to illustrate various concepts in biology and paleontology.

APPENDIX A
Scientific Supply Companies that Sell Casts of Fossils and/or Invertebrate and Plant Fossils for Classroom Use

Dino Productions
P.O. Box 3004
Englewood, CO 80155

Ward's Natural Science
Establishment, Inc.
5100 West Henrietta Rd.
P.O. Box 92912
Rochester, NY 14692-9012

Geoscience Resources
2990 Anthony Rd.
Burlington, NC 27215

Geo Science Industries
4015 S. Taft Hill Rd.
Ft. Collins, CO 80526

Saurus
530 S. 4th East
Centerville, UT 84014

Jones Fossil Farm
East Acres Park
Worthington, MN 56187

APPENDIX B
References for Information on Paleontology and/or Specimen Identification

Arduini, P., and G. Teruzzi. 1986. Simon and Schuster's guide to fossils. Simon and Schuster, New York, 317 pages.

Beerbower, J. R. 1968. Search for the past: An introduction to paleontology. Prentice-Hall, Englewood Cliffs, New Jersey, 572 pages.

Boucot, A. J. 1990. Evolutionary paleobiology of behavior and coevolution. Elsevier Science, New York, 725 pages.

Dott, R. H., Jr., and R. L. Batten. 1981. Evolution of the earth. McGraw-Hill, New York, 113 pages.

Fenton, C. L., and M. A. Fenton. 1989. The fossil book: A record of prehistoric life. Doubleday and Co., Garden City, New York, 740 pages.

Lambert, D. 1983. A field guide to dinosaurs. Avon Books, New York, 256 pages.

———. 1985. The field guide to prehistoric life. Facts on File Publications, New York, 256 pages.

Laporte, L. F. 1979. Ancient environments. Prentice-Hall, Englewood Cliffs, New Jersey, 163 pages.

McKerrow, W. S. 1978. The ecology of fossils. The MIT Press, Cambridge, 383 pages.

Moody, R. 1986. Fossils. Collier Books, Macmillian Publishing Co., New York, 192 pages.

Norman, D. 1985. The illustrated encyclopedia of dinosaurs. Crescent Books, New York, 208 pages.

Pinna, G. 1990. The illustrated encyclopedia of fossils. Facts on File Publications, New York, 240 pages.

Steel, R., and A. P. Harvey. 1979. The encyclopedia of prehistoric life. McGraw-Hill, New York, 218 pages.

Thompson, I. 1982. The Audubon Society field guide to North American fossils. Alfred A. Knopf, New York, 846 pages.

APPENDIX C
Companies that Supply Materials for Molding and Casting

Standard plaster
USG molding plaster No. 1: Available at most lumber yards

Dental stone (plaster)
Hydrocal white: Threewit-Cooper Cement, 2900 Walnut St., Denver, CO 80205
Castone and Glastone: Healthco, Inc. 6555 S. Kenton St., Englewood, CO 80111
Coecal Dental Stone: Coe Laboratories, Inc., 3737 W. 127th St., Chicago, IL 60658

Latex rubber
Cementex No. 80 molding compound: Cementex Latex Corp., 480 Canal St., New York, NY 10013, or
Douglas and Sturgess, 730 Bryant St., San Francisco, CA 94107

Jeltrate
Healthco, Inc. 6555 S. Kenton St., Englewood, CO 80111

Silicone rubber
3110 Silicone Rubber: Dow Corning Corp., Midland, MI 48640

APPENDIX D
Selected Paleontology Laboratory Exercises from the University of Wyoming

Selected exercises from the paleontology laboratory in the General Biology class at the University of Wyoming [Breithaupt, B. H. 1990. Paleontology. Pages 189–203, *in* General biology laboratory manual: Principles (J. M. Beiswenger and R. M. Kitchin, Editors). Burgess Press, Minneapolis, 229 pages]:

Station C

The long fish-like skeleton is a mosasaur, a Mesozoic swimming reptile. It was a highly aquatic lizard closely related to the varanid lizards of southeastern Asia, such as the Komodo dragons. Notice its aquatic adaptations: fish-like tail, flipper-like arms and legs, and streamlined body. Mosasaurs evolved from land-dwelling carnivorous lizards that became adapted for life in the ocean. What recent animals have gone through a similar evolutionary history?

The mosasaurs exhibit convergence with other aquatic vertebrates. Convergence is the independent development of similar characters in lineages that evolved from different ancestors. The independent development of similar characters in lineages evolved from a common ancestor is termed parallelism.

Station I

Before you stands the skeleton of *Apatosaurus* (commonly, although less correctly, called *Brontosaurus*). *Apatosaurus* was 75 feet long and weighed approximately 30 tons. This specimen was collected north of Laramie in Albany County in the Jurassic Morrison Formation. Notice the head of *Apatosaurus*.

What modern animal resembles *Apatosaurus* from its shoulders to its head?

The peg-like teeth were used for eating between 1 and 2 tons of vegetation each day. Notice that all of the teeth are the same shape and size. This is referred to as a homodont dentition. Mammals have a heterodont dentition (differentiation of teeth for various purposes). What difference does your dentition have from that of *Apatosaurus*?

Where in its mouth are its teeth located?

What does this tell you about how this animal ate?

What types of plants did this animal probably eat?

Why are your teeth different?

Station M

Look at the ancestry of the horse display. It depicts horse evolution through time with respect to skull and tooth changes. Look at the Oligocene horse (*Mesohippus*) skeleton in this case. How is this horse different from a modern horse?

Look at the row of five teeth in this display. The most primitive horse tooth is found to the far left. Notice the changes in the size and grinding surfaces of the tooth crowns through time (looking from left to right). Since many evolutionary changes result from natural selection pressures, what factor(s) may have been intimately involved with the evolution of the horse, especially in regard to its teeth and hooves? Hint: See your geological timetable.

Horses in Wyoming today are descendants of those brought over by the Europeans when they discovered the New World. But horses have been in Wyoming for about 50 million years. Paleontological evidence indicates that horses became extinct in North America about 10,000 years ago and had to be reintroduced to this continent in the Holocene. Why might have North American horses gone extinct?

Station P

Notice the common fossil mammal skulls from Wyoming. Of these, name the three without living relatives in this state. When did they live? (See your geological timetable for dates.)

Look at the mammoth tooth. The occlusal (chewing) surface faces the top of the case. Elephants have roughly only four of these teeth in their mouths. What teeth are these homologous with in your mouth?

Notice the plesiosaur paddle and the drawing of a plesiosaur in the display case to your right. Plesiosaurs, like mosasaurs and ichthyosaurs, were highly aquatic, carnivorous Mesozoic reptiles whose ancestors were land-dwellers. Some people believe that the "Loch Ness monster," if it exists at all, is a plesiosaur. How might plesiosaurs have differed in their locomotion from ichthyosaurs and mosasaurs?

Look at the ancient environment display. List two ways that an ancient environment can be determined.

The stingray and fish are from the same fine-grained lake deposits that preserved the palm leaf you observed previously. The freshwater stingray is a member of the Class Chondrichthyes (cartilaginous fish) as opposed to the bony fish (Class Osteichthyes) also represented in this display. Why are complete skeletons of sharks, skates, and rays usually not found in the fossil record?