

## Geologic History and the Oceans

Organisms must adapt to their environment to survive. One of the most remarkable aspects of life is the efficient design of many animals and plants. Think about a shark, for example. Its keen senses and razor-sharp teeth make it such a successful predator that it has lived in the oceans for millions of years.

How do we know? Fossils. Fossils are the remains of organisms preserved in rocks and sediments. We know by studying fossils that the animals and plants on Earth have changed over millions of years. (The science of fossils is called paleontology.) This is one of the reasons that the theory of evolution was formed. The word "evolution" means change over time.

We said that organisms cannot survive unless they adapt to their environment. Therefore, if animals and plants have changed, so has the environment. In the past few decades, scientists have discovered evidence that the ocean has played a major role in worldwide environmental change.

### Geologic Time/Dating Fossils

Marine invertebrates (animals with no backbone) are the most abundant type of fossil. They are so common that many geological periods are based on them. A geologic period is a unit of time when a particular group of organisms was prevalent. Paleontologists speak in terms of "geologic time," where events are thought of in thousands and millions of years.

Determining the age of the Earth and of fossils is not easy. Scientists have two different methods—correlative dating and radiometric dating.

In correlative dating, the paleontologist examines layers of rocks containing fossils and determines which ones are in the upper, middle and lowest layers. Those at the bottom were deposited first and are the oldest. The layer above is younger, and the upper layer is youngest. This method is useful but doesn't give an absolute date.

To get a more accurate date, scientists use radiometric dating. Unstable radioactive isotopes have known decay rates. These are expressed in "half-lives." For example, ten units of an isotope with a half life of 200 years will have decayed to five units between 1900 and the year 2100. By calculating the relative proportion of the radioactive element and its decay products found in a fossil (or in a rock next to the fossil), you can determine how long it has been since that fossil formed.

For example, uranium-235 decays to lead-207. A rock with more uranium-235 than lead-207 is younger than a rock with more lead-207 than uranium-235.

Radioactive isotopes don't occur in every rock. But by combining correlative dating with radioactive dating, a trustworthy age can be obtained.

### The Marine Fossil Record

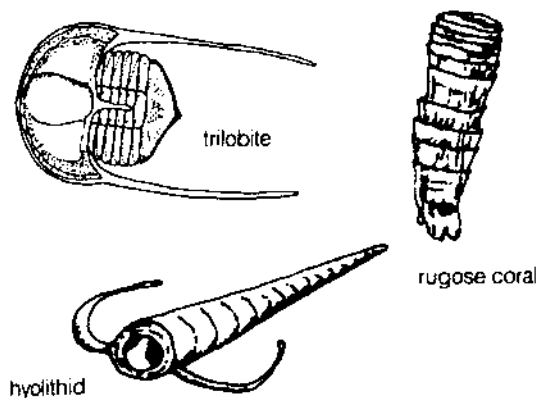
The first forms of life on Earth are believed to have lived in the sea since the earliest fossils are found in ocean sediments. And, you don't have to be a scuba diver to collect them. Fossils of marine organisms can be found in the middle of continents (far from any beach) and even on the tops of mountains. The distribution of the oceans certainly has changed since the Earth was formed. This environmental change may have had a big effect on the evolution of life.

Another interesting thing about marine fossils is the existence of periodic mass extinctions. Hundreds of species disappeared in a geologically short period of time.

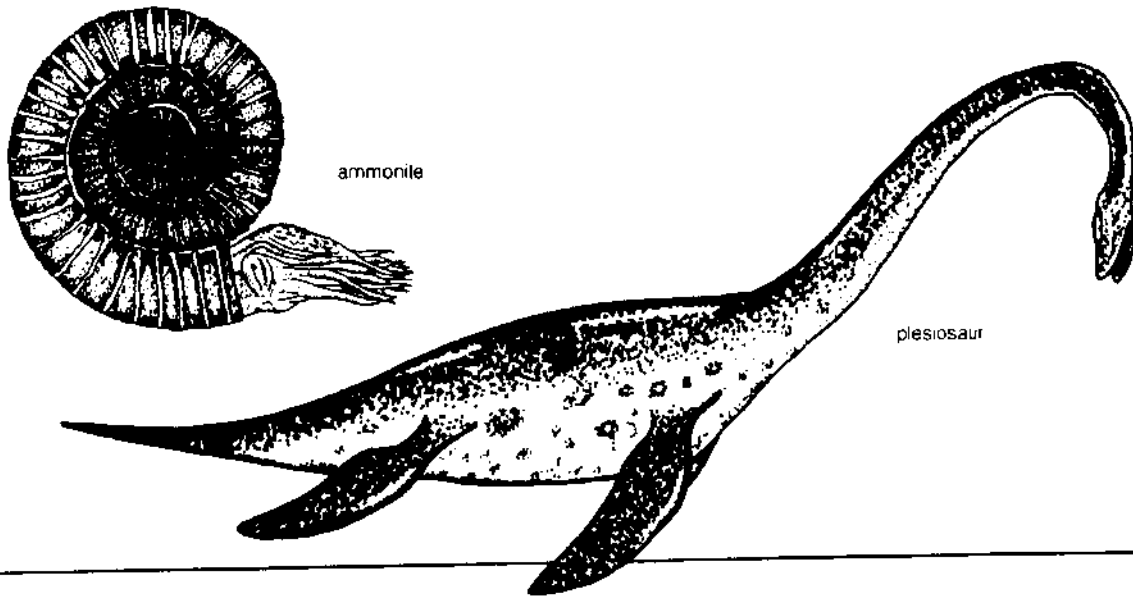
There are many marine creatures that we don't see today as a result of these extinctions (Figure 1 and 2). These include rugose corals, hyolithids, trilobites and plesiosaurs. But there are some marine organisms that have been so evolutionarily successful that they have survived environmental changes since the Paleozoic era and are still with us today (Figure 3).

No one knows exactly why some animals become extinct and others survive, but there are lots of theories.

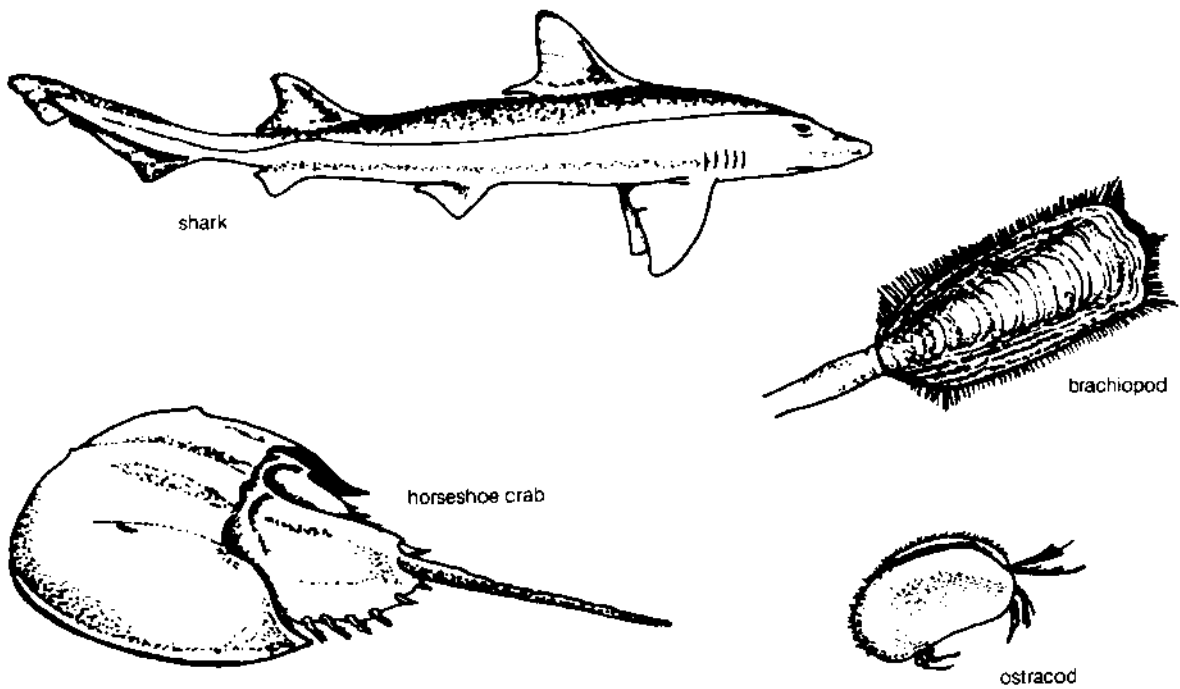
Figure 1 Extinct marine creatures



**Figure 2** Extinct marine creatures



**Figure 3** "Living fossils" in the sea—marine animals that have survived since the Paleozoic era



## Changes in the Oceans

Theories about the causes of mass extinctions often center on the history of the seas. The occurrence of mass extinctions and the abundance of marine fossils on land are evidence that the oceans have undergone dramatic changes in their shape and geographical distribution. Scientists hypothesize that two major processes are responsible—plate tectonics and sea level changes.

### Plate Tectonics

In the 1960s, scientists accepted the idea that the continents have moved since they were formed. As long as maps have existed, people have noticed that the edges of the continents fit together (especially South America and Africa). It was not until recently, however, that it was proved that continents do drift.

Scientists discovered ridges in the middle of the oceans through which hot, new crust seeps (Figure 4). At the edges of some ocean basins, there are deep trenches where old crust is destroyed. This means that the continents are riding "plates" that cover the Earth like a skin. New material is added to a plate at one end (ocean ridge) and destroyed at the other end (trench). This results in constant movement.

This process brought the continents together in the Mesozoic era and gradually pushed them apart. New oceans formed between them. Plate movement continues today, although it is not fast enough to notice. Geologists have used scientific technology to measure the Atlantic Ocean's growth, which is at the rate of approximately one inch a year.

Although this is not significant in our lifetimes, in geologic time such movement makes a big difference. The formation of new oceans changed the distribution of water and altered climate. This may have caused some extinctions.

## Sea Level Changes

When you change the shape of a container (like an ocean basin), you change the level of the water in it. Think of the water level in a short, wide glass versus the same amount of water in a tall, narrow one.

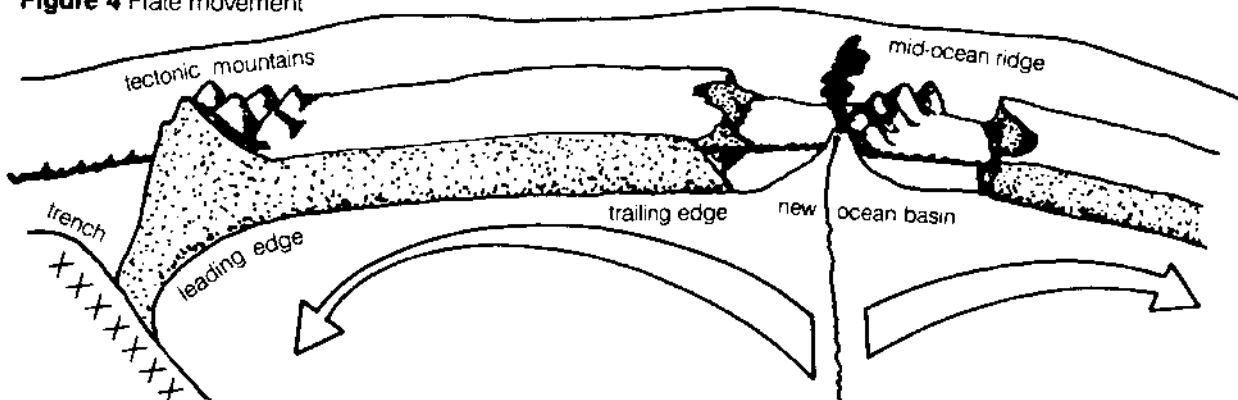
Scientists have plotted the changes in sea level as they correlate to warm and cold climates. The evidence shows that sea level has rarely been stable.

For much of the Earth's history, sea level has been higher than it is today. Then, the ocean covered most of the continents, creating large, shallow seas. The waters were warm, the depth and currents uniform, and the conditions stable. Many different, specialized types of creatures evolved in these oceans. The times of maximum diversity in the fossil record coincide with times of maximum flooding. When sea level dropped and new, deeper basins formed, the organisms that depended on the shallow seas lost their habitat and became extinct. It is possible that the movement of the continents and the changes in sea level have written the course of evolution in the sea.

There are many different theories about mass extinctions. Interestingly, the extinctions of marine fauna coincide with extinctions on land. Why? Some researchers believe that a key species, such as a small fish or algae, formed the base of the food chain for ocean and land animals.

Other scientists have focused on extraterrestrial reasons for mass extinctions. The presence in rocks of meteorite dust (a mineral called iridium) corresponds to times of extinctions. This suggests that asteroids hitting the earth may have caused huge dust clouds to block out the sun and rapidly alter the climate. Other researchers are looking at comets to explain the changes. It is unlikely we will ever know for sure what caused extinctions, but is important to try to understand so we can better predict the future.

**Figure 4** Plate movement



ACTIVITY 1

# Personal Time Line

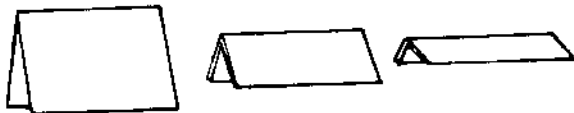
## Purpose

To develop an awareness of the amount of time involved in the evolution of life, to become aware of when complex organisms evolved in geologic time, to see how much evolutionary time is focused on ocean life and to become aware of the oceans as the birth-place of all living things.

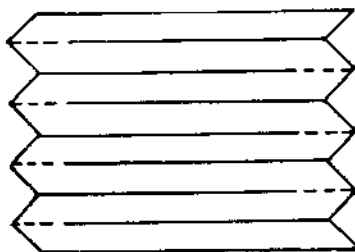
## Materials

- scissors
- colored pencils
- paper
- geologic time scale (textbook for information and data)

**Figure 5** Fold a sheet of paper lengthwise three times



**Figure 6** Draw a line in each crease as indicated



**Figure 7** Fold the paper crosswise three times



## Procedure

Fold a sheet of paper (8½ by 11 inches) in half lengthwise three times. When you unfold the sheet, the creases should make eight sections (Figure 5).

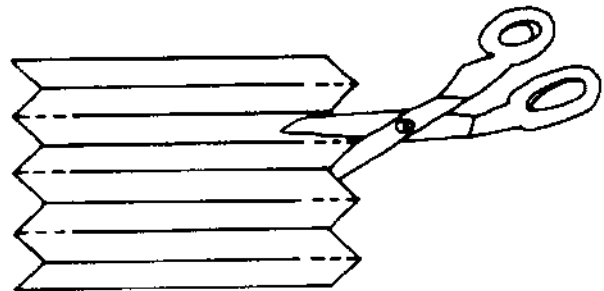
Draw lines like those indicated in Figure 6 at each crease. Fold the paper in half crosswise three times (Figure 7). Unfold and cut along the horizontal lines you drew earlier. Now unfold your time line, bending it over at the joints so that it will lay flat and straight (Figure 8).

Label your time scale. Each crease mark is equal to one million years. Mark the boundaries of the three eras Paleozoic, Mesozoic and Cenozoic. Use the geologic time scale in your textbook to determine the eras. With light-colored pencils, color each era a different color.

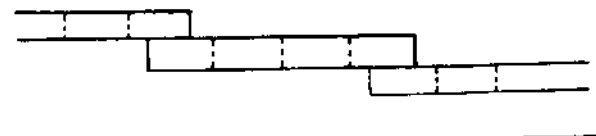
Label the periods (Pre-Cambrian, Cambrian, Ordovician, etc.). In each period, make small drawings of the organisms that were abundant then.

Put a star where there were mass extinctions. Be sure to notice where humans appear.

**Figure 8** Unfold and cut along lines drawn earlier



Unfold time line, bending it over at joints so that it lays flat and straight



## ACTIVITY 2

**A Classroom Geologic Time Line****Purpose**

To develop an awareness of the amount of time involved in the evolution of life, to become aware of when complex organisms evolved in geologic time, to see how much evolutionary time is focused on ocean life and to become aware of the oceans as the birthplace of all living things.

**Materials**

poster board  
scissors  
marking pens  
masking tape or thumbtacks  
meter sticks or tape measures  
calculators

**Procedure**

Cut out large (30 cm wide by 15 cm long) arrows from the poster board.

Using the evolutionary time line from a textbook, prepare as many arrows as the number of significant events you want to portray. On each arrow put when the event occurred. For example, mark these firsts: cell formation, land plants, fish, air-breathing animals, insects, reptiles, birds, mammals, hominids, human beings and modern humans.

Now, measure the total periphery of your room. Take that number and divide by 5. If you assume that Earth is 5 billion years old, then  $\frac{1}{5}$  of the room's periphery will equal 1 billion years.

Now divide the length that equals 1 billion years by 10. That length will equal 100 million years.

Finally, divide the length that equals 100 million years by 100. You will have the length that equals 1 million years.

If the periphery of your room is 50 meters, then 1 million years will be 1 cm. If the periphery is 25 meters, then 1 million years will be .5 cm.

Now, agree on which corner to the room to start. Take your first arrow, marked "Earth is formed—5 billion years ago," and tape it in this corner.

Take the next arrow, marked "First cell formed—2.7 billion years ago," and put it the appropriate distance away from your first arrow according to your calculations.

Continue putting up arrows until you have represented all the major events in the evolution of living things.

**Questions**

1. What are the benefits and disadvantages of radiometric dating?
2. What are the most abundant types of fossils?
3. In which geologic period do we find humans?
4. Name three very ancient types of organisms that are still alive today.
5. What are three possible explanations for the mass extinctions that have occurred over geologic time?
6. How long had the Earth been in existence before the first living cell evolved?
7. When did plant life first appear on land?
8. How long did life exist in the oceans before life first appeared on land?
9. Why did life first evolve in the oceans?
10. How do you explain the vast increase in the diversity of life over time?
11. How did ocean life affect the ozone layer? How did this permit terrestrial life?
12. What is the theory of plate tectonics?
13. What does the word "evolution" actually mean?
14. How can the movement of the continents affect sea level?
15. Why might sea level changes have significantly affected the evolution of marine and terrestrial organisms?
16. Can you think of something that is going on today that might be causing many species of animals and plants to become extinct? Explain.
17. Why should organisms change over time rather than remain the same? What are they reacting to?

18. Let's say that uranium-236 decays to lead-205.  
Which of the rocks below is older (Figure 9)?

- a. more uranium-236  
less lead-205
- b. more lead-205  
less uranium-236

Explain your answer.

---

**Figure 9** Two rocks



More Uranium 236  
Less Lead 205



More Uranium 205  
Less Uranium 236

---

## ACTIVITY 3

**Fossil Lab****Purpose**

To make careful observations, to become familiar with and recognize many different kinds of fossil formations and to interpret observations.

**Teacher Background**

Fossils are excellent teaching materials. Many students are already familiar with and enthusiastic about fossils. They are likely to bring contributions from home for use in the classroom. The incredible age of fossils generates amazement in students and teachers alike. But most important, fossils can be used to sharpen students' observation skills and to lead them to interpret and hypothesize.

Some of the easiest fossils to collect and the most inexpensive to obtain are marine fossils. In fact, the most likely place for a quick burial (before the body can be eaten or rotted away) is in the sea. There, sediments are always collecting in an anaerobic environment, explaining why 90 percent of all fossils are marine organisms. And, those organisms with hard shells are the most likely to leave fossil remains. Finding marine fossils far from today's oceans tells us a lot about the Earth's past.

Even ancient people were aware of fossils, wearing them as amulets and attributing supernatural powers to them. In the Middle Ages, fossils were thought to be vestiges of the "The Great Flood," remains from the trial and error of creation, temptations by Satan, or a trick of nature. Leonardo da Vinci was one of the first people to grasp the implications of fossil remains. But it was not until the early 1880s that paleontology, the study of fossils, became an established science.

There are several types of fossils:

- **Preservation** of complete organisms or parts of organisms in ice, amber or tar.
- **Molds**—an imprint of the actual organism, such as a shell, in mud or sediment. Molds can be of the inside or outside of the shell.
- **Trace fossils**—tracks such as the trail of a horseshoe crab in rock that was once sediment, former "homes" such as preserved mud burrows or tubes from worms, or the feeding traces of worms or other organisms.
- **Petrifications**—replacement fossils, where the original material was dissolved and replaced with minerals.

- **Casts**—The inside of a bivalve, for example, may be filled with minerals that harden, leaving the shape of the shell on the outside.

- **Distillation**—carbon films left by a leaf or an animal. The film may wash away but the impression can be left behind in the rock.

Fossils can tell us many things about the Earth. We can tell the age of a stratum of earth by noting the fossils found in the material. Each geologic era has its characteristic flora and fauna. Thus we determine what kinds of environments existed in different areas of the Earth over time. We can determine the Earth's movements and the shifting of its layers.

In addition, we can use fossils to see how organisms have changed. This helps us understand the vast time involved in evolutionary changes and the interaction between organisms and their environment during evolution. Fossils are even used to locate coal seams and petroleum and gas deposits. Microfossils in deep borings can be indicators of carbon products.

In addition, fossils are valuable in what they don't tell us. Many organisms were not preserved as fossils. This provides the opportunity to gather available data and make interpretations based on incomplete evidence.

The following student activity is designed to provide the student with a "lab practical" environment. The students move around the classroom for 1½ to 2 minutes to observe each specimen and answer a question. The actual fossils and questions will be specifically determined by what the teacher and students have collected. In addition, the lab is best if a few fossils of land organisms (plant and animal) are used to provide for comparison and discussion.

It is suggested that a collection of fossils be obtained. These may be fossils already present at the school or ones from various private collections. Other sources are:

- **Carolina Biological Supply**—GEO 5299 is 15 fossils from the Texasgulf Inc. phosphate mine in Aurora. These are mounted on labeled cards and come with background information. The cost is \$14.

There are other sets available. A larger one with bigger fossils from Aurora costs \$46. In addition, there are individual fossils such as ammonites, crinoids and sand dollars.

- Texasgulf Inc. can be contacted directly. Write the Communications Coordinator, Texasgulf Inc., P.O. Box 48, Aurora, N.C. 27806.

- Also try museum stores (Discovery Place in Charlotte, The Museum of Life and Science in Durham, The N.C. State Museum of Natural Sciences in Raleigh, etc.), gem and mineral stores or science and hobby stores.

- Or collect your own. Educators at the N.C. Aquariums, the N.C. Maritime Museum or the N.C. State Museum of Natural Sciences could direct you to good fossilizing areas.

Try to collect a variety of fossils that represent different geologic periods of formation.

Examples:

**Brachiopods**—These are bivalves. You can find the actual shells, imprints or casts. They are common in rocks of the Cambrian to Carboniferous ages.

**Corals**—The walls and partitions built by tiny soft-bodied creatures long ago decomposed are preserved.

**Trilobites**—These creatures had a head, segmented body and tail section. They roll up like a pill bug and are found in mudstones of the Cambrian to Silurian ages. They can be imprints or replacements.

**Snails (Gastropods)**—These are single-coiled shelled organisms.

**Sea urchins**—The spines are usually missing in fossils.

**Ammonites (Cephalopods)**—These are extinct now but were common from the Jurassic to Cretaceous ages. They are found as replacements or casts.

**Various fish**—These are usually imprints and a fine example of marine vertebrate fossils.

**Whale bone**—These are easy to find in North Carolina and are an excellent example of minerals replacing tissue but leaving the porous bony appearance.

**Sharks' teeth**—These are easy to find and can be used to illustrate how one part of an organism can be used to extrapolate other data.

**Tube worm homes**—These are harder to find but not impossible.

**Insects encased in amber**—These must be bought. They are expensive but nice to have.

**Petrified wood**—Carolina Biological Supply has some samples from the West for about \$6.

**Horse teeth, plant imprints, internal casts, sand with miniature fossils, fossil feces (coprolite), etc.** can be collected.

Always include in your collection at least one example of something that is not a fossil. You can even let the students know there is an imposter. It will sensitize their observation powers. You might use a piece of pyrite (fool's gold), a dead beetle, a barite desert rose, uncut geode or a snake skin. Use your imagination.

## Student Procedure

Around the room you will see 30 stations. Each station has one fossil and a question. Observe the fossil and answer the question. After about two minutes, you will be asked to shift to the next station. Repeat the process.

At the end of the lab, you will have time to return to any fossils you wish to observe longer. Answer these questions as best you can, remembering that sometimes even the experts disagree. Among the fossils will be some impostors. See if you can identify the materials that are not fossils.

Remember that fossils are by definition the actual remains or evidence of living organisms that lived in the past. They may be impressions, casts, parts of the organism or mineral replacements of bone or shell.

## Teacher Procedure

Provide students with a sheet that has the questions for each station printed out next to the station number. Each student starts with the question that corresponds to his first lab station and continues from there in numerical order. This saves the student time and allows more time for observing and thinking. For some stations, students will need a dissecting microscope or magnifier.

Here are some sample questions for various fossils. The types of fossils at each station are in parentheses. Do not include these on the cards next to the fossils or on the handout. These are for your information only.

## Sample Questions

1. (shark teeth)

Shark teeth are commonly found at the bottom of the ocean, but other parts of the shark are rarely found there. Suggest a reason for this.

2. (mold of a seashell)

What type of fossil is this and how was it formed?  
What environment would these animals have lived in?

3. (trilobite from Utah)

Was the animal that formed this fossil soft- or hard-bodied? Explain. What was the environment like 500 million years ago in Utah?

4. (petrified wood)

What does this sample have in common with wood?  
What does this sample have in common with rock?

5. (leaf film)

Fossil evidence suggests that much vegetation found in Canada today is similar to what was found 14,000 years ago in our area. Suggest an explanation for this.

6. (shellacked fish)

Is this a fossil? Why or why not?

7. (spider in amber)

How might this spider have been preserved so completely?

8. (ammonite cast/mold)

What kind of fossil is this? What kind of environment did this organism live in?

9. (fossil coral)

What is the common name of this fossilized organism?  
What used to live in the tiny holes?

10. (leg bone [femur] of large mammal)

Is this a fossil? Why or why not?

11. (shark's tooth)

Is this an example of actual remains or replaced remains? Explain.

12. (arrowheads)

What are these? Are they fossils? Why or why not?

13. (fossil fern [Pennsylvanian] and fossil coelenterate [Mississippian])

If the coelenterate fossil was found in a deeper stratum of rock in the same location as the fern fossil was found, which do you think was older? Why? What must have happened to the area over time?

14. (fish print [Wyoming])

How do you think this fossil was formed? I thought Wyoming was where "the deer and the antelope play." Why was this fossil found there?

15. (whale vertebra)

This is a fossil. What part of the anatomy of a large animal is it? This was an ocean-dwelling organism. Any guesses?

16. (gastropod)

Is this fossil a mold or a cast? Explain.

17. (piece of pyrite [fool's gold])

Is this a fossil? Why or why not?

18. (plant pod [pseudoivory] and fern film)

One of these is a fossil. Which one? Explain.

19. (Chesapeake Bay fossil scallop)

Fossils of this type are common. Was this organism more abundant than other species that lived at the same time? Why or why not?

20. (cast of a bivalve)

What kind of fossil formation is this? What kind of organism was it?

21. (sycamore leaf [carbon film])

What kingdom did this organism belong to? What was the environment like when and where this organism lived?

22. (petrified wood)

How many years ago did this organism first appear on Earth? Certain fuels are often associated with an abundance of these organisms. Cite two examples of these fuels.

23. (plaster cast of mastodon molar)

This is a plaster cast made from a fossil or part of a mastodon. What part of the mastodon is this?

24. (oreodont teeth [pig-like creature])

Was this animal a herbivore or carnivore? Explain.

25. (fossil long bone)

What is this a fossil of? Was the organism a vertebrate or an invertebrate? Explain.

26. (fern frond and branch of another plant on same piece of rock)

Are the branch and leaves in this fossil from the same type of organism? Explain.

27. (two trilobite fossils in same rock)

How many fossil organisms are here? What kind of environment do you think they once lived in?

28. (tube worm homes)

What kind of organisms were these? What kind of environment do you think they once lived in?

29. (rock with many small molds of marine organisms)

There are fossils on both sides of this rock. Are they all from the same species? Explain.

30. (two samples of whale vertebrae [one is noticeably heavier])

Lift both of these fossils. Can you explain the difference in weight?

31. (marine vertebrae [small])

What do you think these pieces of marine skeleton are?

## Competency Factors/References

### Competency Indicator

#### Biology—

- 1.1 know about the nature of science;
- 1.2 know the methods of science; and
- 1.3 know the limitations of science.

### Competency Measures

#### Biology/Academic—

- 1.1.3 give scientific evidence to support the theory of evolution;
- 1.2.1 perform laboratory exercises that use process skills such as observing, interpreting data and formulating conclusions; and
- 1.3.1 explain the limits of time, experience and society on scientific problem-solving when given an example of a problem facing past generations.

### References

- Brownlee, Shannon. "Cycles of Extinction," *Discover*. May 1984, pp. 22-24.
- Carter, J.G., P.E. Gallagher, Enos Valone and T.J. Rossbach. 1988. *Fossil Collecting in North Carolina*. N.C. Department of Natural Resources and Community Development, Division of Land Resources, Geological Survey Section, Raleigh.
- Gramwell, Martyn. 1983. *Understanding and Collecting Rocks and Fossils*. Usborne Publishing Ltd., London.
- McCormack, Alan J., Arnold I. Miller and Robert Motzko. 1980. *Biology Laboratory Manual*. Scott, Foreman and Co., Glenview, Ill.
- Rhodes, Frank H.T., Herbert Zim and Paul R. Shaffer. *Fossils, A Golden Guide*. Golden Press, New York, Western Publishing Co., Racine, Wis.
- Spence, Lundie and Dirk Frankenburg. 1989. *North Carolina Marine Education Manual: Coastal Geology*. UNC Sea Grant, UNC-SG-78-14A, Raleigh, N.C.
- Thompson, Ida. *Audubon Society Field Guide to North American Fossils*. Alfred A. Knopf, Inc., New York.
- Wilbur, Amy. "A Dynamic Planet," *Science Digest*. March 1986, pp. 52-53.

