SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center
Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center
Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center
Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers
Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center
Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers
Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center
Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers
Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center
Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers
Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*
Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site
UPR Lab H.S.

* * * * * * * * * * * *

Pilot Sites
Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C., William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

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Project Associates

Bill G. Aldridge
SciEdSol, Henderson, Nev.

Dorothy L. Gabel
Indiana University

Stephen D. Druger
Northwestern University

George Miller
University of California-Irvine

Student Materials

Learning Sequence Item:

1006

Evolution and the Fossil Record

May 1996
Adapted by: Tom Hinojosa

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Lab Activities

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Readings

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This micro-unit was adapted by **Tom Hinojosa** (SS&C Center Coordinator, Santa Clara, Calif.)

Science as Inquiry/
History and Nature of Science

Pictures from the Past

What can we determine about the evolutionary sequence of life from limited data?

Overview:

Life in the past occurred in a huge variety of types and sizes, just as it does today. You have organized various groups of living things by their shape, structures, and various other physical characteristics (morphology), but in this activity you will consider the order in which some of the first living organisms evolved. What kind of life forms were first to evolve, simple or complex? Simple organisms are those consisting of few parts or basically similar components without any or much ornamentation or sophistication. Complex organisms are made up of dissimilar parts or parts in intricate relationships. For example, which is more complex, a dog or a worm? What does the level of complexity indicate about each living thing? Why are some living organisms more complex than others? What level of complexity would you expect to find among the first living organisms?

Procedure:

The illustrations in this activity are of fossils of what are thought to be some of the earliest living things (Fig. 1). Since they are illustrations, and not the actual fossils, we have no way of determining their actual age. However it is known that the earliest one is from about 3.4 billion years ago (3,400 million) and that the most recent one is from about 900 million years ago. You must determine the proper evolutionary sequence for these ancient organisms and develop a reasonable criteria to support your conclusions. Cut-out and examine each of the pictured life forms. Give each one a scientific name for easy identification during discussions and create a data table in which to record your given names and a detailed description of each organism. Develop a criteria or rating system that will help you put the pictures in their proper evolutionary sequence. Write-out your criteria and share it with your teacher and/or other students for comments and feedback. Make a list of all the organisms in the order in which they evolved including how long ago you propose each organism first appeared. Finally, develop a simply stated theory of evolution which supports your proposed sequence.

Name	Description	Relative Complexity Rating

Questions:

1. How would you describe the difference between the simplest and the most complex organism in this activity?

2. In the process of the evolution of life forms, which would you expect to have evolved first, simple or complex organisms? Why?

3. Some of the earliest life forms thought to have existed on Earth are forms of bacteria. Which of the life forms in this activity seem similar in structure to bacteria? Would you consider them relatively simple or complex?

4. The pictures give you only limited information about the organisms. Fossils are the remains, impressions, or other evidence of the former existence of life preserved in rock. What kind of fossils of these types of organisms would you expect to find? What problems in finding such fossils can you think of? What further information/data can real fossil specimens provide that drawings on paper can not?

5. Even fossils give you limited information about the living organism. If the actual organisms were found well-preserved, what information could you collect that would help you refine your sequence?

Fossil Organisms

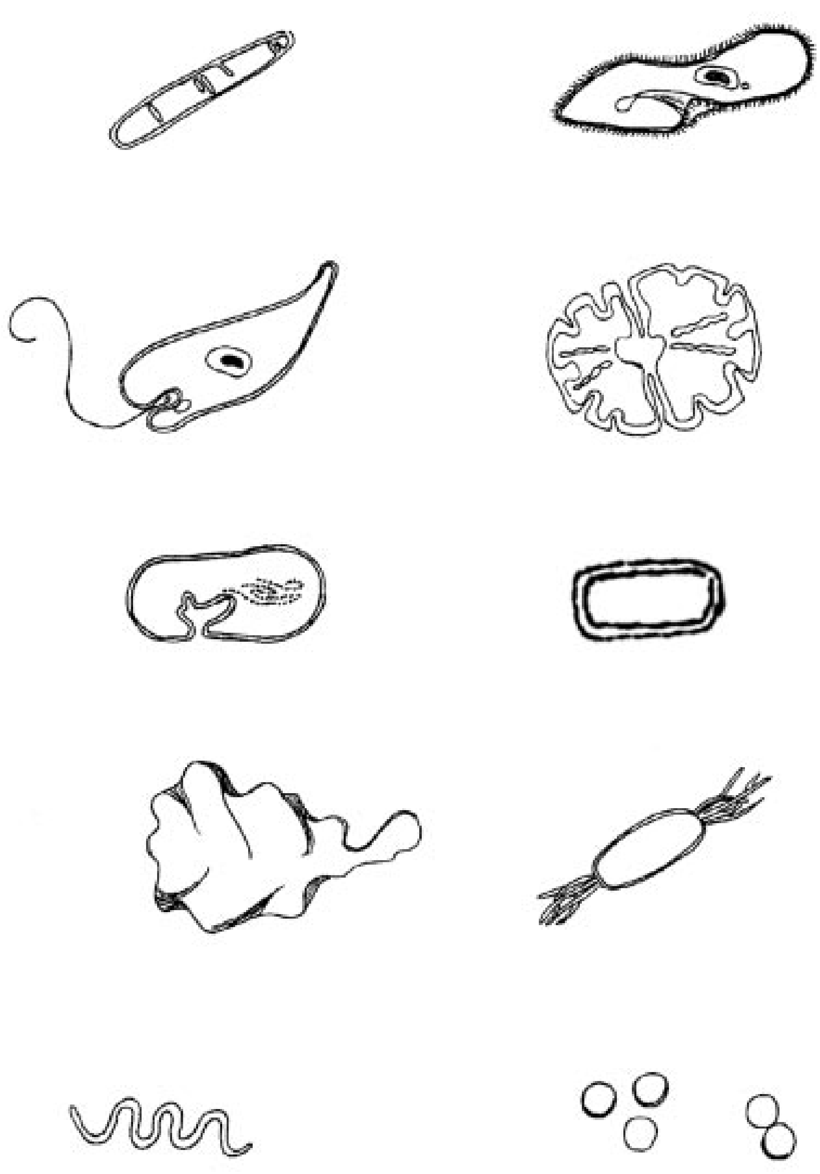


Fig. 1.

Student Sheet

Science as Inquiry/
History and Nature of Science

The Plot Thickens

What do fossils tell us about the evolution of life forms?

Overview:

Fossils are the key to knowing how areas of the earth have changed and how life evolved. Some areas once underwater are now above sea level. Similarly, some areas once above water are now submerged. The rock record abounds with evidence of past life of certain periods in the earth's history in the form of fossils. Are any of these life forms around today? How do the fossils compare to common modern life forms? The rock which contains the fossils can now be dated using modern technology and techniques. What stories do the rocks tell? How accurate a picture of ancient life and evolutionary history can you come up with based upon the fossil record?

Procedure:

Carefully study the fossil records in this activity (Figs. 1–7), including the available fossils (simulated or real) and the labeled illustrations. Determine and record the appropriate dates during which each organism lived. Note the type of organism (soft-bodied, invertebrate, plant, etc.) each fossil seems to be from and its relative complexity of body form. Arrange them in sequence from oldest to youngest. Note any apparent trends in their appearance or body form. Now, study the graphs which depict the distribution and diversity of some major groups of vertebrates beginning about 500 million years ago (Fig. 8). Note any general trends you observe in the data. Based upon the available data and discussions with your lab partners (and other students), describe in detail—including approximate dates for evolutionary events—the history of biological evolution during the time period , from approximately 1 billion years ago to about 360 million years ago. Remember to include your conclusions from Activity 1.

Questions:

1. How does the sequence of evolution of life forms as indicated by the fossil record compare to the order of organisms that you determined in Activity 1?

2. What type of fossils seem most abundant? What does this indicate about life during these ancient times? What are some other possible explanations for why these types of fossils are found in such abundance?

3. Based on the fossil evidence, what can you conclude about the overall ecological conditions on the earth during these ancient times?

4. Does the fossil record presented here support your theory of evolution from Activity 1? Explain.

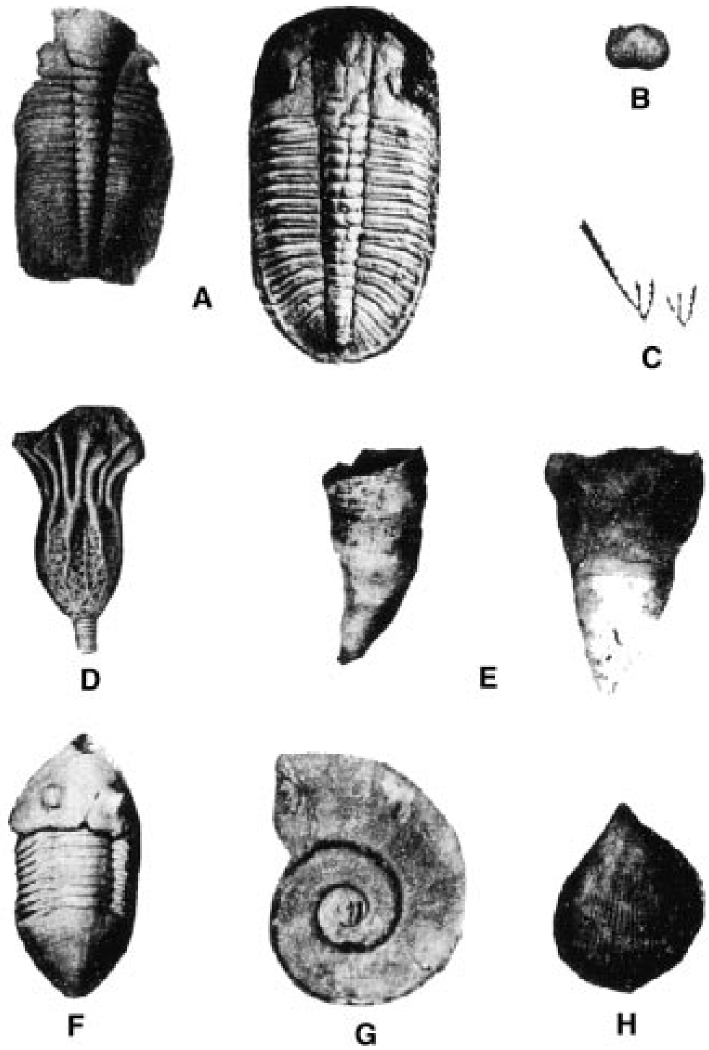


Fig. 1. Sample fossils. About 1/2 natural size. Ages range from 570–455 million years ago. A) trilobites; B) brachiopod; C) graptolites; D) crinoid; E) horn coral; F) trilobite [more recent form]; G) cephalopod; H) pelecypod.

Univ. of Michigan Museum of Paleontology, images A, B, C, E, F, H.
Univ. of Minnesota Paleontological Collection, image D.

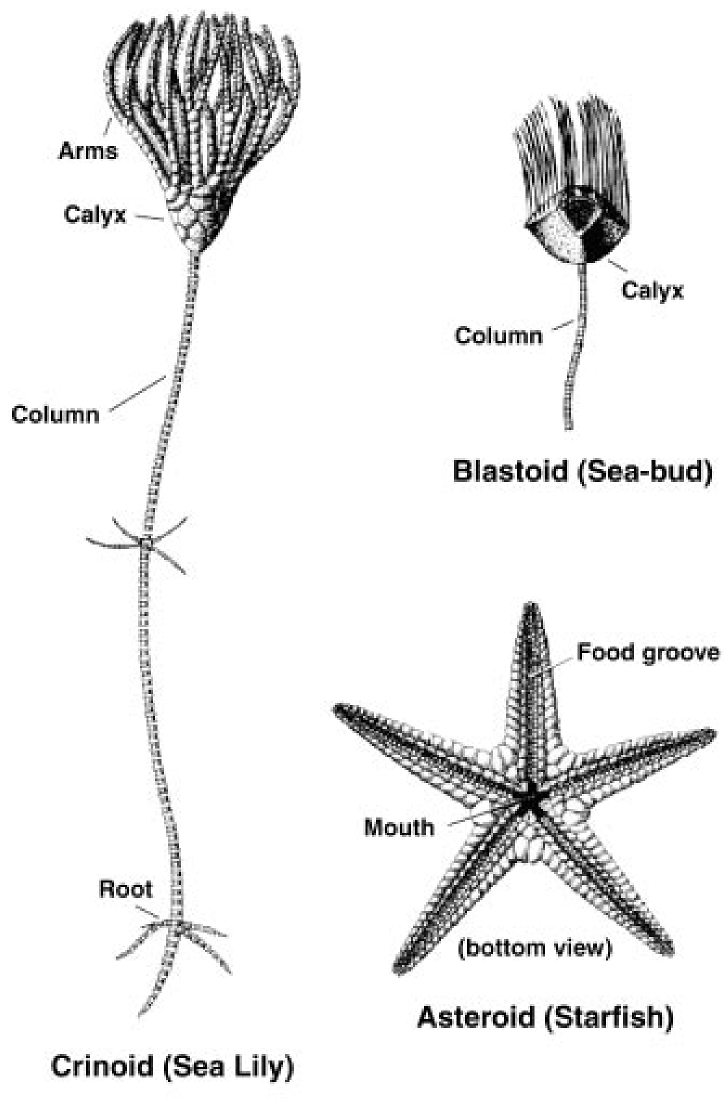


Fig. 2. Sample fossils. Sketches of three different echinoderms. Ages range from 510–440 million years ago.

After Zumberge, J. H., *Elements of Geology*, New York: John Wiley & Sons, Inc., 1959.

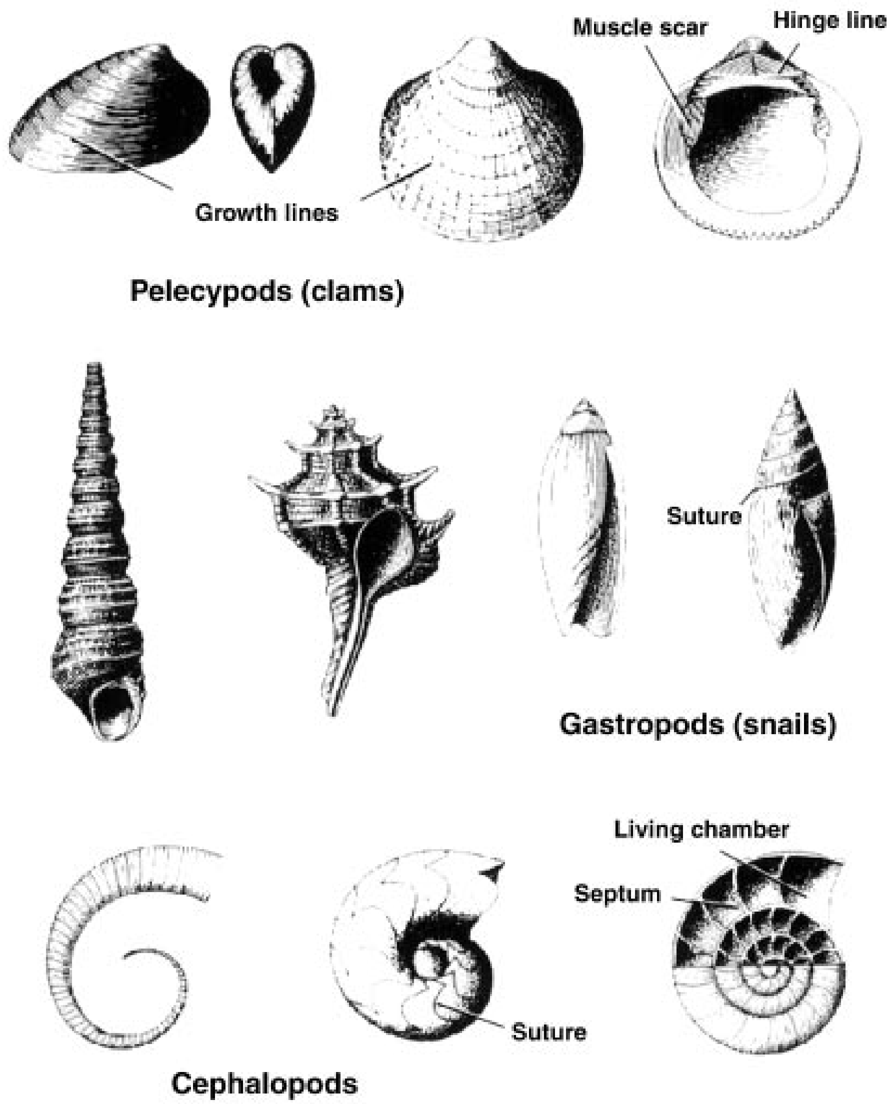


Fig. 3. Sample fossils. Sketches of mollusks. Some are natural size. Ages range from 510–445 million years ago.

After von Zittel, Karl A., Textbook of Paleontology, New York: The MacMillan Co., 1899.

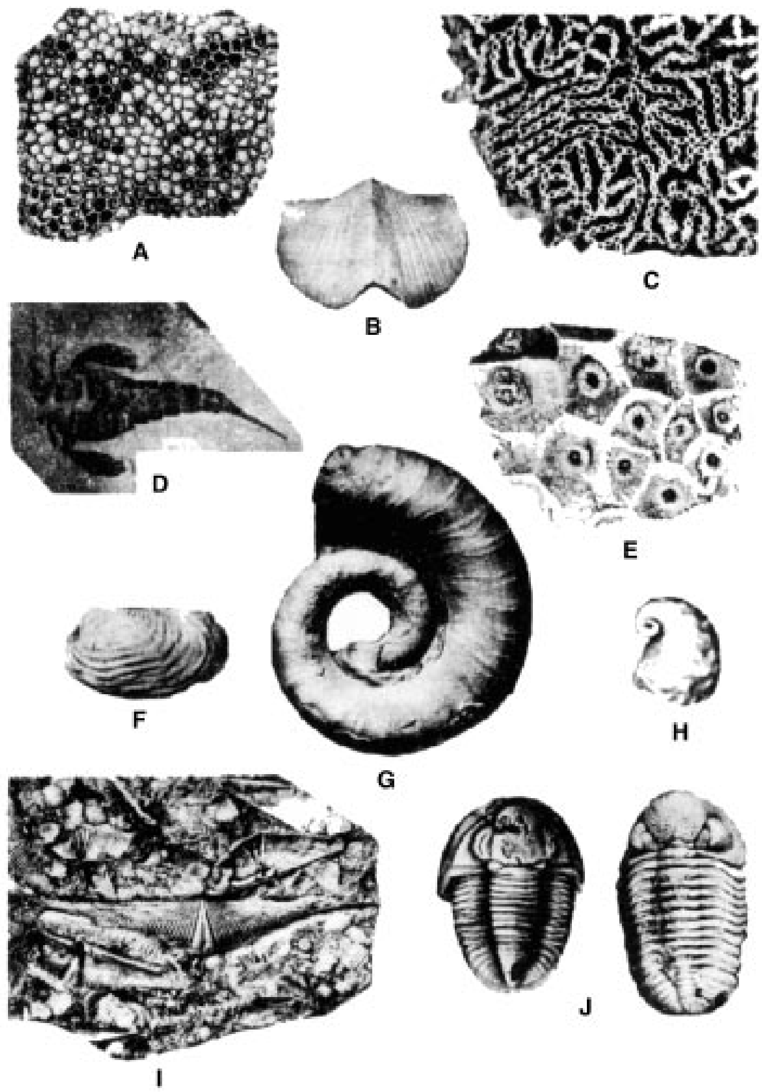


Fig. 4. Sample fossils. About 1/3 natural size. Ages range from 440–410 million years ago. A) honey-comb coral; B) brachiopod; C) chain coral; D) eurypterid; E) colonial coral; F) pelecypod; G) cephalopod; H) gastropod; I) brachiopods; J) trilobites.

Ehlers, George M., and Erwin Strumm, Univ. of Michigan Museum of Paleontology, images A, B, C, E, F, G, H, I.
Sloan, Robert, Univ. of Minnesota Paleontological Collection, image D.

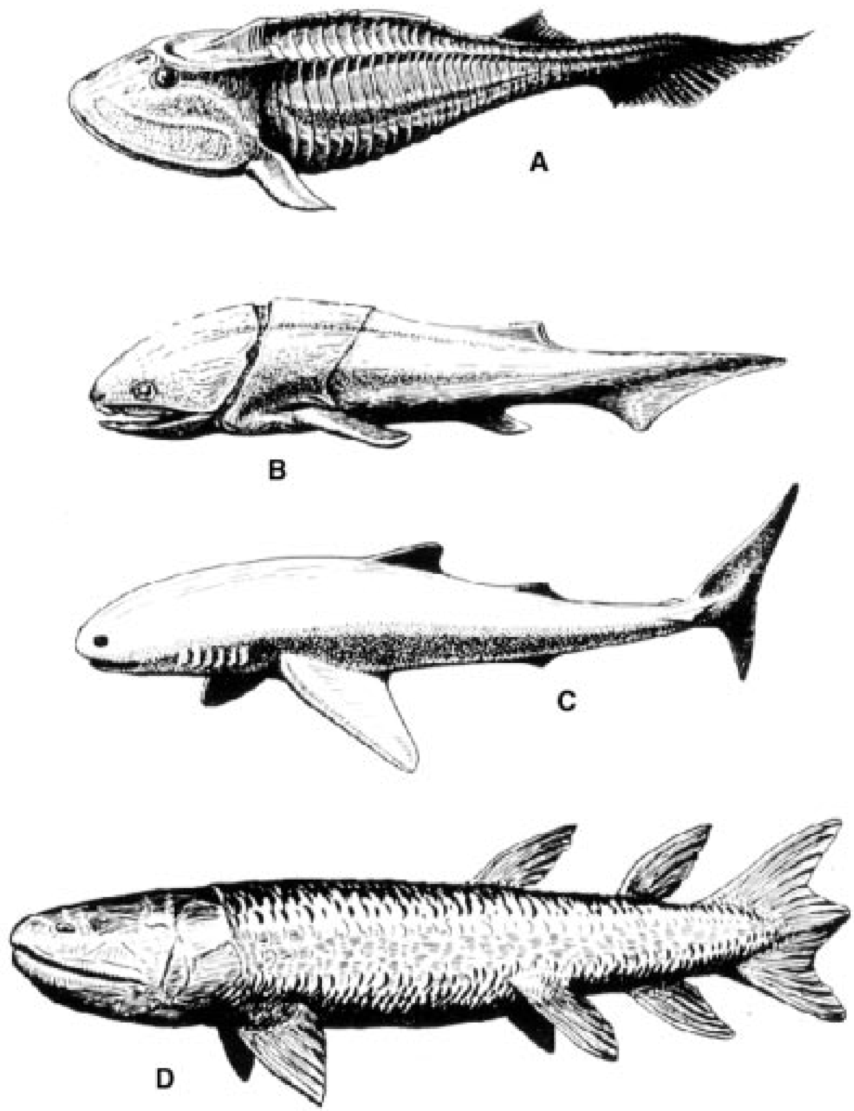


Fig. 5. Sample fossils. Ancient fishes [based on composite fossil records]. Ages range from 410–355 million years ago. A) ostracoderm; B) placoderm; C) shark; D) crossopterygian.

After Colbert, Edwin, *Evolution of the Vertebrates*, New York: John Wiley & Sons, Inc.

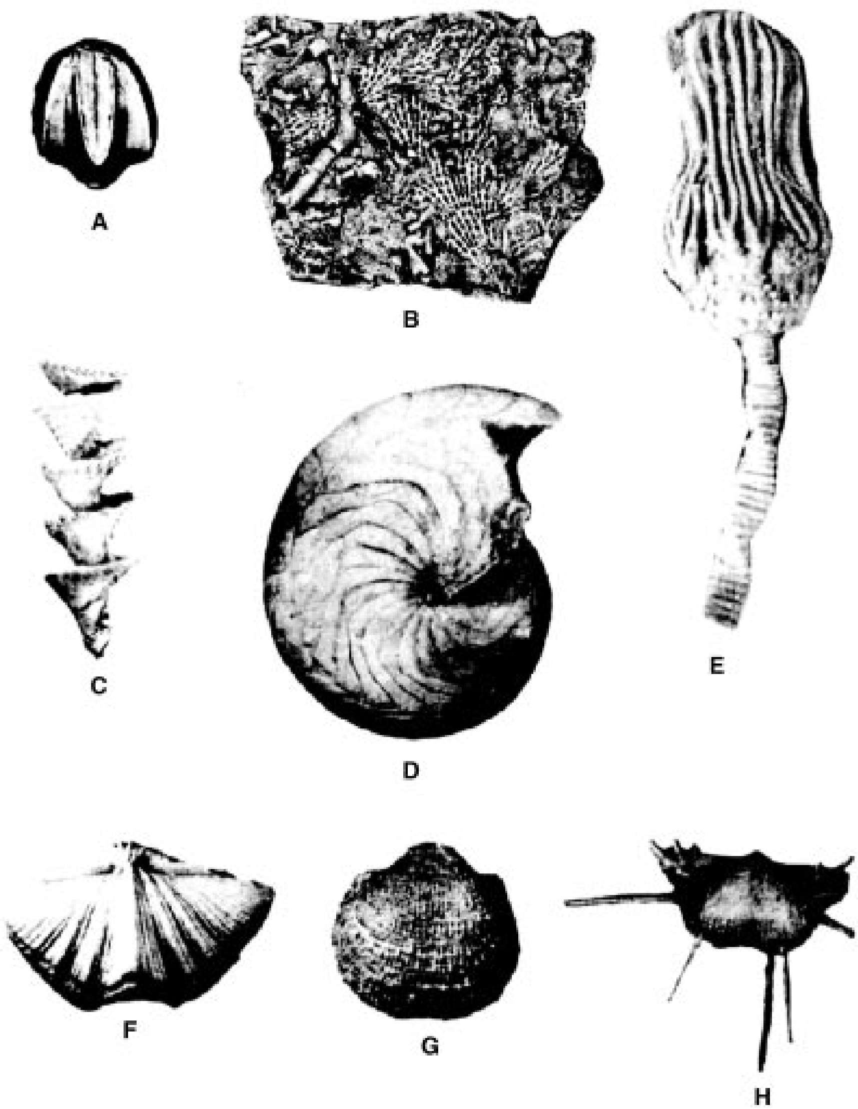


Fig. 6. Sample fossils. About 1/2 natural size. Ages range from 380–260 million years ago. A) blastoid; B) bryozoa; C) bryozoa; D) cephalopod; E) crinoid; F) brachiopod; G) brachiopod; H) brachiopod [more recent form].

As appearing in Zumberge, J. H., *Elements of Geology*, New York: John Wiley & Sons, Inc., 1959, from Univ. of Michigan Museum of Paleontology.

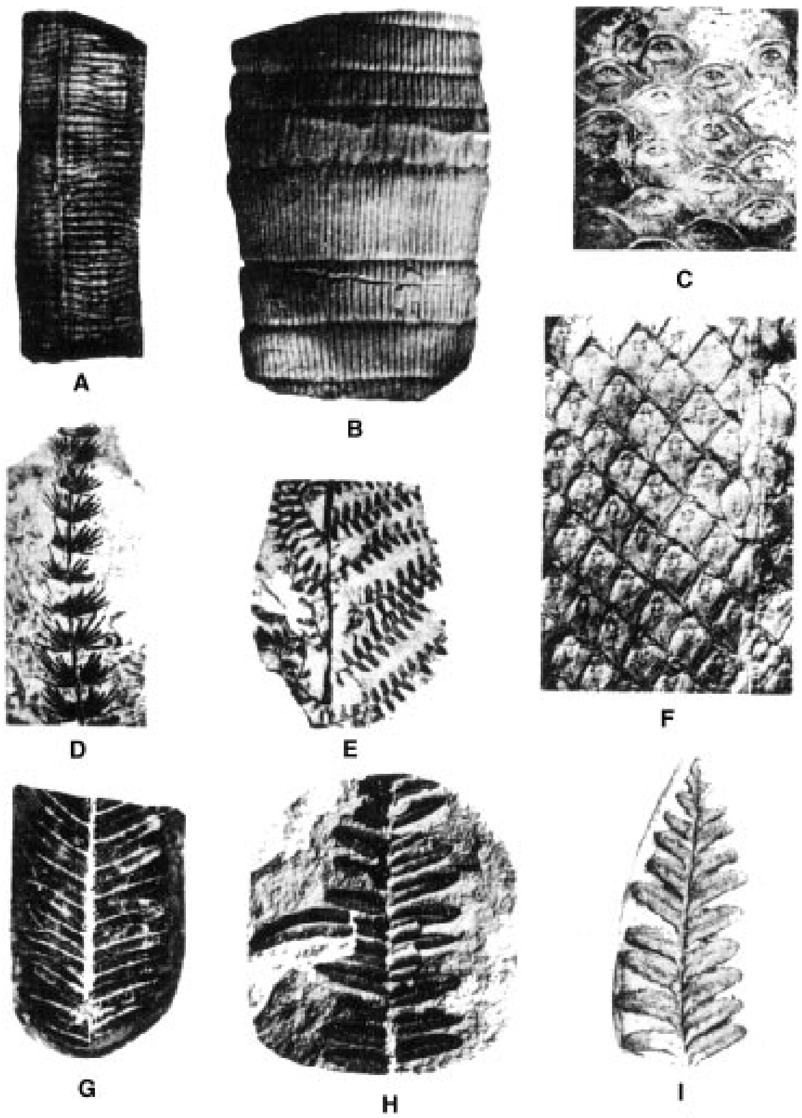
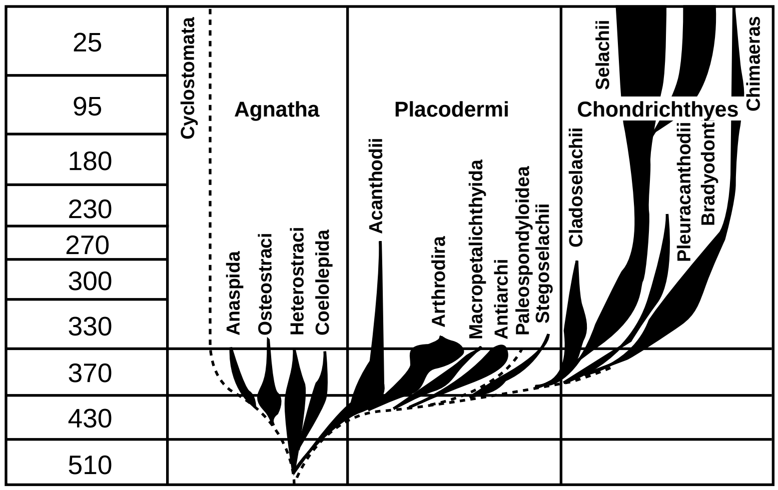
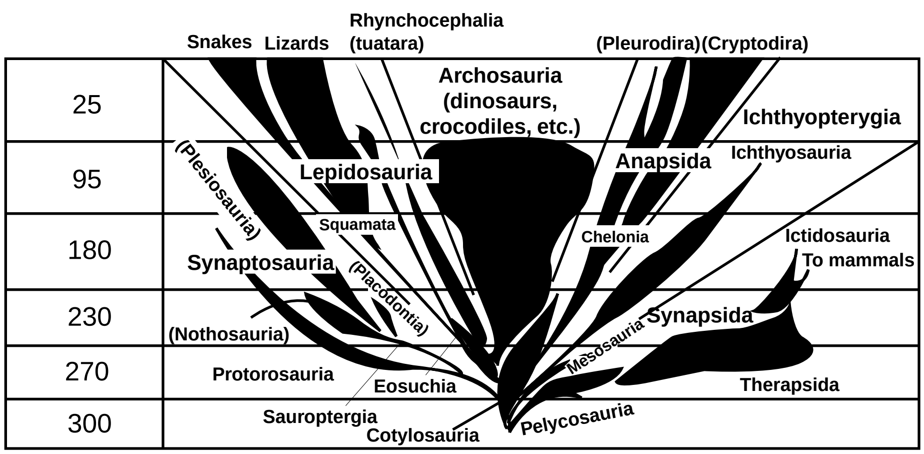


Fig. 7. Sample fossils. Plants. About 1/2 natural size. Ages range from 320–290 million years ago. A) cordaites; B) calamites; C) sigillaria; D) calamites foliage; E) fern; F) ? G) seed fern; I) seed fern.

Arnold, Chester A., *An Introduction to Paleobotany*, New York: McGraw-Hill Book Co., 1947.



Three Classes of Fishlike Vertebrates



Reptiles

Fig. 8. Disttribution and diversity of some major groups of vertebrates. Chronological distribution and very approximate changes in diversity of two major groups of vertebrates. Width of the bar is proportional to diversity observed in the fossil record. Broken lines indicate inferred but not observed presence at that time. Lineages are joined to indicate hypothesized phylogenetic relationships. Numbers in the left column refer to millons of years ago, i.e., 25 = 25 million years ago.

Futuyma, D. J., *Evolutionary Biology*, 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.

Science in Personal and
Social Perspectives

Turn Out the Lights, the Party's Over

When did mass extinctions occur on Earth and what are some possible causes?

Overview:

We hear of endangered species and possibility of the extinction of various modern species on a regular basis. "Save the whales," "protect the mountain gorillas," and "don't buy ivory, protect the elephants," are some familiar popular causes of recent times. The decline of such species usually have multiple causes, some of which are unique to the particular endangered species and others which play equally on other species, but for various reasons, the others have managed to stave-off the threat without becoming threatened themselves. Imagine, however, a world where up to 90% of all existing species become endangered relatively suddenly, all at the same time. What could cause such a situation and could it actually occur? In fact, mass extinctions have occurred several times during the history of life on the earth. Fossil and geologic evidence indicates that mass extinctions occurred world-wide five different times, 440 million years ago, 365 million years ago, 250 million years ago, 215 million years ago, and most recently, 68 million years ago. Could it happen again? If it did, which phyla of living organisms are likely to survive and why? In this activity, you will learn about such occurrences in the past and consider what circumstances or conditions could cause such a devastating catastrophe worldwide.

Procedure:

Work in groups as directed by your teacher. Study the "Geologic Time Scale" and "North American Rock Record" included in this activity. Note any trends or patterns that seem to occur in the major events of the various geologic time periods. Now review the approximate dates of the mass extinctions known to have occurred given in the overview above. Develop and record a preliminary hypothesis as to what may have caused each of the mass extinctions. Note whether they each may have had unique contributing circumstances or whether there may have been common factors contributing to several or all of these catastrophic events. Your hypothesis should be based on the information in the tables and logical inferences and conclusions you can draw from that information, not on unfounded speculation. For example, the first mass extinction coincides with the diversification of certain invertebrate and vertebrate phyla and the beginning of Appalachian mountain building.

Discuss whether something about this process could have led to the demise of multiple existing creatures of that time. Note questions and any additional information your group decides must be obtained to better understand what was happening at the time. Your materials include several readings on this question of what could have caused the mass extinctions. Cover the readings as a group either by reading each selection or by assigning one or more readings to each member of your group in order to obtain and share some ideas that have been proposed by scientists to explain the possible reasons for the mass extinctions. Afterwards, come up with a final group hypothesis to explain each mass extinction listed above. Be sure to support your hypothesis with information, data, or observations about the conditions and circumstances which existed on earth at the particular times. Your teacher may direct you to other resources to help you in your research.

Questions:

1. What difficulties did you have in trying to solve the mystery of the 5 mass extinctions?

2. What are some possible sources of further information that could help you get closer to determining the exact cause(s) of each of the mass extinctions?

3. Do you think another mass extinction could occur on the earth? Explain your reasoning.

4. Describe a likely cause of a mass extinction yet to occur. What type of organisms would you propose have the greatest chance of survival? Explain what it is about them that makes their survival more likely than other species.

5. If any of the possible causes described in the readings were to occur again in modern times, what, if anything, could humans do to prevent a world-wide mass extinction?

Geologic Time Scale

Era	Period	Epoch	Millions of years from start to present	Major Events
Cenozoic	Quarternary	Recent (Holocene) Pleistocene	0.01 2.0	Repeated glaciations; extinctions of large mammals; evolution of Homo sapiens; rise of civilizations.
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	5.1 24.6 38.0 54.9 65.0	Radiation of mammals, birds, angiosperms, pollinating insects. Continents nearing modern positions. Drying trend in mid-Tertiary.
Mesozoic	Cretaceous		144	Most continents widely separated. Continued radiation of dinosaurs. Angiosperms and mammals begin diversification. Mass extinction at end of period.
	Jurassic		213	Diverse dinosaurs; first birds; archaic mammals; gymnosperms dominant; ammonite radiation. Continents drifting.
	Triassic		248	Early dinosaurs; first mammals; gymnosperms become dominant; diversification of marine invertebrates. Continents begin to drift. Mass extinction near end of period.
Paleozoic	Permian		286	Reptiles, including mammal-like forms, radiate amphibians decline; diverse orders of insects. Continents aggregated into Pangaea; glaciations. Major mass extinction, especially of marine forms, at end of period.
	Carboniferous (Pennsylvanian and Mississippian)		360	Extensive forests of early vascular plants, especially lycopsids, sphenopsids, ferns. Amphibians diverse; first reptiles. Radiation of early insect orders.
	Devonian		408	Origin and diversification of bony and cartilaginous fishes; trilobites diverse; origin of ammonoids, amphibians, insects. Mass extinction in late period.
	Silurian		438	Diversification of agnathans, origin of placoderms; invasion of land by tracheophytes, arthropods.
	Ordovician		505	Diversification of echinoderms, other invertebrate phyla, agnathan vertebrates. Mass extinction at end of period.
	Cambrian		570	Appearance of most animal phyla; diverse algae.
Pre-Cambrian	Vendian		670	Origin of life in remote past; origin of prokaryotes.
	Sturtian		800	Origin of later eukaroytes; several animal phyla near end of era.

North American Rock Record

Time Period millions of years	Geologic Events
0–2	West coast uplift continues in U. S. Great Lakes form.
1–2	Ice Age. Raising of mountains and plateaus in Western U. S.
2–5	N. America joined to S. America. Sierras and Appalachians re-elevated by isostatic rebound.
5–23	N. America joined to Asia. Volcanism in Northwest U. S., Columbia Plateau.
23–37	Alps and Himalayas forming. Volcanism in Western U. S.
37–53	Coal forming in the Western U. S.
53–65	Uplift in Western U. S. continues.
65–135	Uplift of Rockies begins. Colorado Plateau raised. Coal swamps in Western U. S. Intrusion of Sierra Nevada batholith.
135–205	West-central N. America under huge sea. Gulf of Mexico Atlantic Ocean begin to form.
205–250	Volcanism and faulting along East coast. Palisades of Hudson formed.
250–290	Final uplift in Appalachians. Ice Age in S. America. Salt-forming deserts in Western U. S.
290–320	Great coal-forming swamps in N. America and Europe.
320–355	Extensive submergence of continents.
355–410	Mountain building continues in New England and Canada. White Mountains raised.
410–440	Salt-and-gypsum-forming deserts in Eastern U. S.
440–510	Beginning of Appalchian mounting building. Taconic and Green Mts. form. Half of N. America is submerged.
510–570	Extensive deposition of sediments in inland seas.
570–?	Great volcanic activity, lava flows, metamorphism of rocks.

Science in Personal and
Social Perspectives

My Life's Work

What effects do living things have on their environment?

Overview:

What would Earth be like if no living things had ever existed here? The geologic record indicates that before life evolved, and probably for a long time thereafter, Earth had an atmosphere without free oxygen. Most forms of life today, with the exception of certain anaerobic bacteria, require free oxygen in the air in order to survive. So, how did such an atmosphere and other conditions we see today come to be? Apparently, ancient bacteria needed to absorb the element hydrogen from the environment, and slightly later photosynthetic blue-green algae appeared in great abundance. From these beginnings came the subsequent explosion of diversified life forms which evolved into all known living things. What effects did this rapid evolution have on the earth's environment? Could it be that the animals and plants themselves have something to do with creating an environment suited for their own survival? In this activity you will study a very basic question of how plant and animal life might affect the environment.

Procedure:

Label five test tubes for easy identification. You will use a pH indicator which changes color depending on the presence of an acid or a base in each of the test tubes. Create a data table suitable to record your observations of the initial color of each test tube solution, the pH, color changes, and any other notable changes that occur in the test tubes.

Sample data table

Test Tube	Color at start	pH at start	Observations after 30 min. color	bubbles
1. Control (acid)				
2. With Elodea				
3. Control (neutral)		pH 6–7.6		
4. Control (base)				
5. With Elodea		pH 6–7.6		

Place equal amounts (20 mL) of distilled water in each test tube to serve as the media for testing the effects of animal and plant respiration on the environment. You will need to determine pH changes in each tested media, so add the appropriate indicator to each test tube. Be sure to note the initial color of the test tubes when the indicator is first added. (Note: bromthymol blue will create a greenish color in neutral water solutions—pH 6.0 to 7.6, yellow in acid, blue in base.) Use two of the test tubes to test for the effects of animal respiration and plant photosynthesis on the environment.

Blow into the two test tube solutions until you observe a color change indicating an effect. In one of the two test tubes test the effect of plants by adding a sprig of Elodea plant. Set these aside while you prepare the other test tubes. One will serve as an overall control. In the second test tube, create a control representing a basic solution by adding 1 or 2 drops of an appropriate base. Then, add a sprig of Elodea to the remaining test tube. All five test tubes should be placed in a suitable holder then placed in a situation which encourages photosynthetic activity in the Elodea sprigs. Make careful notes of what happens over the next 30 minutes.

Questions:

1. How would you explain any bubbles you may have observed on the leaves of the Elodea plant?

2. How do you explain the color change caused by animal respiration? What substance in your breath could mix with the water to cause such an effect?

3. What evidence of photosynthesis and its effect on the environment have you observed in this experiment? How could ancient plants affect the atmosphere which contained little or no free oxygen?

4. Consider the rapid evolution of plants and animals beginning about 600 million years ago. Describe what effects this rapid evolution might have had on the environment.