SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

This project was funded in part by the National Science Foundation. Opinions expressed are those of the authors and not necessarily those of the Foundation. The SS&C Project encourages reproduction of these materials for distribution in the classroom. For permission for any other use, please contact SS&C, National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000.

National Science Teachers Association

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*

*not part of the NSF-funded SS&C Project.

Advisory Board

Dr. Rodney L. Doran (Chairperson), University of Buffalo

Dr. Albert V. Baez, Vivamos Mejor/USA

Dr. Shirley M. Malcom, American Association for the Advancement of Science

Dr. Shirley M. McBay, Quality Education for Minorities

Dr. Paul Saltman, University of California-San Diego

Dr. Kendall N. Starkweather, International Technology Education Association

Dr. Kathryn Sullivan, Ohio Center of Science and Industry

Project Associates

Bill G. Aldridge
SciEdSol, Henderson, Nev.

Dorothy L. Gabel
Indiana University

Stephen D. Druger
Northwestern University

George Miller
University of California-Irvine

National Science Education Standard—Earth and Space

The Origin and Evolution of the Earth System

Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the Earth's atmosphere, which did not originally contain oxygen.

Teacher Materials

Learning Sequence Item:

1006

Evolution and the Fossil Record

May 1996
Adapted by: Tom Hinojosa

Evolution of Life, Bacteria and Algae, and Oxygen in the Atmosphere. An examination of the fossil record will introduce students to the evolutionary sequence of life forms. Of particular interest is the pre-Cambrian/Cambrian boundary, which is distinguished by a burst of life. Students should consider the extinctions of the Paleozoic era and examine their possible causes. They should examine the rapid evolution of life forms in the late Paleozoic to early Paleozoic and the effect of this rapid evolution on the atmosphere. (*Earth and Space Sciences, A Framework for High School Science Education, p. 153.)*

Contents

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

1006

Learning Sequence

Evolution of Life, Bacteria and Algae, and Oxygen in the Atmosphere. An examination of the fossil record will introduce students to the evolutionary sequence of life forms. Of particular interest is the pre-Cambrian/Cambrian boundary, which is distinguished by a burst of life. Students should consider the extinctions of the P aleozoic era and examine their possible causes. They should examine the rapid evolution of life forms in the late P aleozoic to early Paleozoic and the effect of this rapid evolution on the atmosphere. *(Earth and Space Sciences, A Framework for High School Science Education, p. 153.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Pictures from the Past **Activity 1**		Turn Out the Lights, the Party's Over **Activity 3**	Pictures from the Past **Activity 1**
The Plot Thickens **Activity 2**		My Life's Work **Activity 4**	The Plot Thickens **Activity 2**
What's the Evidence? **Assessment 1**			What's the Evidence? **Assessment 1**
Atmospheric Evidence **Assessment 2**			Atmospheric Evidence **Assessment 2**
Cut Off in Time, 2 **Assessment 5**			It's All in the Fossils **Assessment 3**
			Cut Off in Time, 1 **Assessment 4**
			Cut Off in Time, 2 **Assessment 5**

Suggested Sequence of Events

Event #1

Lab Activity

1. Pictures from the Past (30–40 minutes)

Event #2

Lab Activity

2. The Plot Thickens (40–45 minutes)

Event #3

Lab Activity

3. Turn Out the Lights, the Party's Over (90 minutes)

Event #4

Lab Activity

4. My Life's Work (40–45 minutes)

Event #5

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Appenzeller, Tim, "Searching for Clues to Ancient Carbon Dioxide," *Science*, Vol. 259, No. 5097, Feb. 12, 1993, pp. 908–909.

Attenborough, D., "The Early Atmosphere," *Life on Earth*, Boston, Mass.: Little, Brown and Co., 1979, pp. 21–22.

"Evolution: Trees as Mass Murderers," [In the News: Breakthroughs], *Discover* Magazine, Vol. 15, No. 2, February 1994, pp. 21–22.

Kerr, Richard A., "Geoscientists Contemplate a Fatal Belch and a Living Ocean," *Science*, Vol. 270, No. 5241, Dec. 1, 1995, pp. 1441–1442.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

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:

Students will study pictures representing fossils of various simple life forms and rank them in order of evolutionary sequence. Without knowing the actual age of the pictured fossils, they must determine a reasonable criteria for establishing the likely evolutionary sequence of such life forms based on observable properties such as apparent morphological complexity. This will set the stage for a study of fossil evidence in the next activity.

Materials:

Per lab group:
sample fossil images (Student Materials)
scissors
ruler, metric

Procedure:

Students cut out and study pictures of various life forms, give each a name, and write a detailed description of each one. Encourage them to use the format for scientific names that they practiced in previous micro-units. (Practice using the rules, not using the actual names since the drawings are generalizations or composites of organisms typical of the Pre-Cambrian Era.)

Name	Description	Relative Complexity Rating

Students may have difficulty at first deciding what is notable in terms of observations and descriptions of the organisms pictured. Tell them to start with simple descriptions of shape, number of parts, partitioned or not, etc., and have them note questions that they have—such as the size, color, and behaviors of the organisms. They use this information to sequence the organisms in a data table. The data table shown is a suggestion—encourage the students to develop their own design.

In order to sequence the organisms, the students must first devise a criteria for determining the relative ages of the organisms, i.e., how long ago the organisms lived. Most students will decide that the simpler organisms must have evolved first, followed by more complex life forms. If this is the case, suggest that the students devise a complexity rating scale from 1–10 and assign a rating to each organism by designating the simplest pictured organism as a "1" and the most complex pictured organism as a "10." They then create written criteria for sequencing the organisms. For example, 1 = simplest life forms, single part; 2 = simple life form, more than one part but simple shape; 3 = more than two parts, simple shape etc. The organisms should be listed in order from simplest to the most complex. Tell the students it is possible that more than one organism could receive the same position in the sequence (thus indicating that the organisms evolved simultaneously) and that they need to include this information in their data tables.

Background:

There are no clear-cut answers or solutions to sequencing the organisms in this activity. This activity is intended to give students an introduction to the evolutionary sequence of life forms by getting them to develop a line of logic (based on evidence) concerning biological evolution theory. The drawings are purposely vague (lacking detail) in some cases just as most fossil evidence is often lacking certain details that would make identification or classification much easier. Encourage students to discuss and argue alternative proposed sequences.

The mechanisms by which living matter arose from nonliving materials are not to be found in the fossil record; organic chemical reactions do not fossilize. The origin of life is a matter of informed speculation and laboratory experiment (Orgel 1973 and Dickerson 1978 provide reviews). It is agreed that whatever the exact steps might have been which gave rise to life, the evolution of life began with complex molecules forming relatively simple micro-life forms. The earliest fossil indications of life are in South African rocks dated 3.4 - 3.1 billion years old, which contain forms that resemble bacteria, including Cyanobacteria (the blue-green bacteria or “algae”), and stromatolites—mound-like structures that are still formed in parts of Australia by Cyanobacteria. The earliest known organisms, then, were prokaryotes, apparently capable of photosynthesis. (This does not imply that the first organisms were photosynthetic; they were probably heterotrophic.) The Cyanobacteria and other prokaryotes appear to have dominated for almost two billion years (see Schopf 1983 on Precambrian life). The earliest known eukaryotes, probably green algae, are in 0.9 billion-year-old rocks, although there is some evidence that they go back to about 1.5 billion years. These organisms do not fossilize easily and their discovery occurred relatively recently.

Variations:

The pictures in this activity are representations of bacteria, blue-green algae, various prokaryotic forms, and a representative eukaryotic cell. Photographs (contained in many biology texts) of these samples may serve as a substitute for the picture cards, but should not be called fossils. Students could be told that the pictures are very similar to the known early life forms and are being used for comparison purposes only. You could label and post such photos around the room and have student lab groups visit each “station” to collect data/observations of each one and then carry-out the same analysis of complexity as described in the activity.

Adapted from:
Futuyma, D. J., *Evolutionary Biology,* 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.
Zihlman, A. L., *The Human Evolution Coloring Book,* Oakville, Calif.: Coloring Concepts, 1982.

Science as Inquiry/
History and Nature of Science

The Plot Thickens

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

Overview:

Students will study fossil records from the Precambrian and Cambrian Periods and from most of the rest of the Paleozoic Era, about 286–570 million years ago (mya). They will also examine graphs showing chronological distribution and changes in diversity of major groups of vertebrates over the same time periods. The students will thereby be presented with evidence of the appearance of abundant, diverse forms of invertebrates which marks the beginning of the Cambrian Period and the Paleozoic Era in general.

Materials:

Per lab group:

fossil kit, styrene (basic set of 20 includes samples from Precambrian and Paleozoic Era; Science Kit and Boreal Laboratories, #66011-10, class quantity: 10 kits @ $67.50, 1/800-828-7777)

fossil images (Student Materials)

Procedure:

Students work in groups of 3 or 4. They study fossils (simulated or real) along with keys identifying common fossils and associated time periods. Students consider two graphs which show chronological distribution and changes in diversity of reptiles and three classes of fish-like vertebrates over a period of time approximately 500–100 mya. They are not given the names of the associated geologic periods the time span represents, because the focus should be on the evolutionary sequence and trends in phylum diversification, not on naming the specific geologic periods when these life forms existed.

Background:

Phanerozoic time embraces all of Earth's history from the end of the Vendian period of the Precambrian—and is divided into the Paleozoic, Mesozoic, and Cenozoic eras. Because the eras and periods of the Phanerozoic were originally defined by their distinct fossil faunas, the borders between them are marked by the diversification of major new groups of animals (see geologic time scale included in these materials).

The Precambrian Era lasted for about 4 billion years. It began with the formation of the Earth and ended about 600 mya. Due to erosion, crustal movements and volcanic activity, very few early Precambrian rocks still exist. However, areas of late Precambrian rock, called shields, are found on each continent. Hardly any fossils are found in Precambrian rocks—only the kingdom Animalia has a promising early fossil record. The first complex, multicellular animals, the Ediacaran fauna, are dated at about 640 mya (Precambrian). These fossils include traces of burrows and tracks as well as a number of soft-bodied animals—some of which have been interpreted as polychaete annelid worms, coelenterates, and possibly soft-bodied arthropods.

The Paleozoic Era began about 600 mya and ended about 230 mya. The continents were close together, the sea level was high, and shallow seas covered parts of continents. The appearance of abundant, diverse forms of invertebrates marks the beginning of the Cambrian period (about 590 mya). During the Cambrian, all the animal phyla with skeletons (which fossilize) appear—many in profusion. These include the Arthropoda, represented by the Trilobites, Brachiopoda, Mollusca (including gastropods, bivalves, and cephalopods), Porifera, a great variety of classes of Echinodermata, and several of the "minor phyla (e.g., Nemertea and Pogonophora) that apparently have existed at low diversity from the Cambrian to the present. Many remarkably well-preserved soft-bodied animals have been found in the Burgess Shale of British Columbia, which includes animals in about 10 extinct phyla that are known only from this formation. The Burgess Shale also contains the earliest known chordate. The origin of vertebrates, however, is not well recorded by fossils. The earliest vertebrate remains, in 510 million-year-old marine deposits of the upper Cambrian are fragments of the external armor of ostracoderms, a group of jawless, finless "fishes" that are more abundantly represented in the Ordovician period.

It is considered likely that all the animal phyla became distinct before or during the Cambrian, for they appear fully formed—without intermediates connecting one phylum to another. Thus, our understanding of the phylogenetic relationships among the phyla is based upon inferences from their anatomy and embryology.

The chronological periods of the rest of the Paleozoic Era are characterized by increased diversification of the various phyla dominating each period. In the Ordovician (505 mya), diversification of echinoderms and other invertebrates; in the Silurian (438 mya), diversification of agnathans and invasion of the land by tracheophytes and arthropods; the Devonian (408 mya), origin and diversification of bony and cartilaginous fishes, diversification on trilobites, origin of amphibians and insects; Carboniferous (360 mya), extensive forests of early vascular plants, diversification of amphibians, first reptiles, radiation of early insect orders; and in the Permian (286 mya), reptiles—including mammal-like forms, radiate, diversification of insects, continents aggregated into Pangaea.

The late Paleozoic Era was a time of dramatic changes. The continents collided, producing larger land masses. Mountains formed. Shallow seas drained into oceans. Towards the end of the era, climates became drier and colder. Rocks of the last period, the Permian, show evidence of extensive glaciers in some parts of the world. It was during this time that the first forests appeared—although they looked nothing like the forests of today. The bulk of today's coal beds formed from these Paleozoic forests. By the end of the Paleozoic Era (about 230 mya) life was firmly established on land.

Variations:

Students attempt to draw or illustrate a typical scene depicting life during the Cambrian Period or early Paleozoic Era. They include not just those organisms indicated by the fossils, but also flora and fauna logically indicated in terms of ecological relationships by the fossil records.

Adapted from:
Danielson, E. W., and E. J. Denecke, *Earth Science,* New York: Macmillan Publishing Co., 1989.
Futuyma, D. J., *Evolutionary Biology*, 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.
Zihlman, A. L., *The Human Evolution Coloring Book*, Oakville, Calif.: Coloring Concepts, 1982.
Zumberge, J. H., *Elements of Geology*, New York: John Wiley & Sons, Inc., 1959.

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.

Teacher Sheet

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:

Students will consider the extinctions of the Paleozoic Era and examine their possible causes. They will formulate a preliminary hypothesis based on information contained in this activity, then revise their hypothesis in light of information and ideas described in contemporary reading selections included in the student materials.

Materials:

Per lab group:
geologic time scale (Student Materials)
North American rock record (Student Materials)
additional resources on theories of causes of mass extinctions, as available.

Procedure:

Students work in groups of 3 or 4. The students consider records of 5 mass extinction events which occurred since the Cambrian period. They study concurrent geological events as indicated by the rock record of the North American Continent in an attempt to determine if there is any reasonable causative relationships between geological or ecological events and processes and the occurrence of each of the mass extinctions. They should note any trends or patterns that seem to occur in the major events of the various geologic time periods. Students develop preliminary hypotheses about possible causes of each of the mass extinctions. You should check their preliminary hypotheses to see that they are justifiable based upon information and resources the students have available to them rather than wild speculation for which the students can cite no supporting evidence. The students then review the readings included in this micro-unit which address contemporary views and hypotheses concerning possible causes of the mass extinctions and re-evaluate their own ideas in light of the information contained therein. You may wish to direct student groups to assign different readings to each member of the lab group such that each member shares responsibility for contributing new information to the group's overall hypothesis. After considering the readings, the students develop a final hypothesis to explain each of the 5 mass extinctions. Have them present their conclusions to the entire class and/or create a poster summarizing their hypothesis and supporting evidence.

Background:

Of all the species that have lived on the Earth since life first appeared here 3 billion years ago, only about one in one-thousand is still living today. All the others, the vast majority, became extinct, typically within ten million years or so of their first appearance. This large extinction rate has had an important influence on the evolution of life on Earth—the population and repopulation of an ecological niche by species after species allows for the testing of a much wider range of survival strategies than the slower process of phyletic transformation by which a species gradually adapts its morphology and behavior to its surroundings. This in turn has contributed greatly to the current level of biodiversity on the planet. There is nothing, however, to suggest that the species alive at present are special in any way. Presumably, they too will become extinct within the next 10 million years or so, and make way for successors themselves.

The importance of extinction to the development of life leads us to some crucial questions about the process, the most fundamental of which is this: Is extinction a natural part of the evolution process, or is it simply a chance result of occasional catastrophes besetting either single species (such as diseases) or larger groups of species (such as changes in the salinity of the sea, or changes in the climate)? Many opinions and theories have been proposed on either side of this debate. It seems likely that the truth lies somewhere between these two basic models involving some interaction between the evolution process and environmental stresses to produce a distribution of extinctions as seen in the fossil record.

Amongst paleontologists, there is some debate about whether mass extinctions are qualitatively different from “normal’ extinction rates, or are simply quantitatively extreme cases in a continuum of extinction rates. Mass extinctions may fit comfortably into the uniformitarianism that has guided geology all along and represent merely high rates of the same processes that have caused extinction throughout the Phanerozoic. If they are qualitatively different events, however, they may have had truly unusual causes—catastrophic, nonuniformitarian, interruptions of the normal course of earthly events. There is the further problem of whether each of the five major mass extinctions had a different cause or whether a single explanation holds for all.

At one time or another, almost every conceivable catastrophe, terrestrial or extraterrestrial, has been advanced to explain mass extinctions—often without evidence. Confounding the search for an explanation is the possibility of multiple events acting in a summative fashion to create extraordinary circumstances which could cause extinction of a wide variety of phyla somewhat simultaneously. Hypothesis and explanations include collisions of an asteroid with the Earth, mountain building, massive volcanic activity, regressions of sea level that reduce the area of continental shelf and effectively eliminate the epicontinental seas, massive runoff of sediments from emerging forestation of land masses, sudden release of massive amounts of stored carbon dioxide from the ocean depths in association with global climate changes, and, since the mass extinctions of the Phanerozoic occurred with a regular period of about 26 million years, an implication of a common extraterrestrial cause. There seems to be no clear consensus at this time.

There is evidence that in some groups the survivors of mass extinctions tended to be the more ecologically and morphologically generalized species—that is, the simpler and broad ranging species may have had a greater survival rate than others, but these properties may not have been the crucial elements for survival through all of the five mass extinction events. Research in this area is ongoing. The chief impact of the mass extinctions was the obliteration of many forms of life whose like has never reappeared. The great periods of extinction were intervals in which the ecological stage was reset for whole new evolutionary dramas only partly touched by what had gone before.

Variations:

This activity presents an excellent opportunity for assigning students research projects for which they seek out multiple references/resources and consider complex ecological relationships throughout geologic time. Student groups could give presentations of their findings and conclusions with ensuing classroom debates on the topic. The mystery of mass extinction creates a compelling reason for in-depth study of any of the five associated time periods with integration of geological, meteorological, and biological events and processes.

Adapted from:
Futuyma, D. J., *Evolutionary Biology,* 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.
Spaulding, N., *Earth Science*, Lexington, Mass.: D. C. Heath and Co., 1994.

Teacher Sheet

Science in Personal and
Social Perspectives

My Life's Work

What effects do living things have on their environment?

Overview:

Students consider the effect rapid evolution during the Paleozoic Era might have had on the atmosphere and the environment in general by doing a simple study of the affects of animal respiration and plant photosynthesis on the pH of a water solution.

Materials:

Per lab group:

beaker, 400 mL
graduated cylinder, 25–50 mL
test tube, 18 mm x 150 mm, 5
straw, soda type
lamp or strong light source, goose-neck high intensity
bromthymol blue indicator, 25–50 mL
distilled water, 200 mL
Elodea plant
sodium hydroxide, 25 mL, 1 M
test tube holder

Procedure:

Students work in groups of two or more. The students label 5 test tubes and create a data table. They place 20 mL of distilled water in each test tube, then add 5 to 10 drops of bromthymol blue indicator solution to each one. The water will turn a greenish color. This dye is green in neutral solutions (pH 6.0 to 7.6), yellow in acid, and blue in base. Taking the first two test tubes, the students blow through the straw into the water of tubes 1 and 2 until the solution changes from green to yellow. This shows that an acid has been formed. The chemical reaction for the formation of the acid is: $CO_2 + H_2O \times H_2CO_3$ (carbonic acid). The double arrows show that the carbonic acid can change back to carbon dioxide and water. The students keep test tube 1 as a control, and add a sprig of Elodea to tube 2. The students then prepare tubes 3, 4, and 5 as follows: Tube 3 with water and bromthymol blue (control); tube 4 with 1–2 drops of 1 M sodium hydroxide

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		

(control)—the color changes from green to the blue of the base and thereby becomes a control representing a basic solution; and tube 5 with the indicator solution and water, and a sprig of Elodea. The students place all 5 test tubes in the 400-mL beaker and place it under the strong light of a high intensity goose-neck lamp which will stimulate photosynthesis in the Elodea. The students observe the test tubes over a period of 30 minutes, looking for color changes and noting whether bubbles appear on the leaves of the plant. Bubbles indicate the production of oxygen. They record all observations in their data table.

Background:

The environment in which organisms evolved has undergone vast changes in which astronomical influences, the dynamics of the Earth itself, and the activities of organisms, have all played a role. Before life evolved—and probably for a considerable time thereafter—Earth had a reducing atmosphere without free oxygen. The evolution of photosynthetic organisms about 3.2 billion years ago created the oxidizing atmosphere. On the continents, organic soils are the product of communities of terrestrial vegetation dating from the Silurian, about 438 mya. The earliest known organisms were prokaryotes, apparently capable of photosynthesis. By about two billion years ago, photosynthetic activity had created an oxygen-rich atmosphere, which must have led to the demise of many anaerobic early organisms. Some such organisms, such as methanogenic bacteria and their relatives, still persist in anaerobic environments, and are so different from other bacteria in the sequence of their RNA that it has been suggested that they have constituted a separate, anaerobic lineage for 3.5 billion years. Note: “The Early Atmosphere” (Reading 4) goes very well with this activity.

Variations:

None suggested.

Adapted from:

Bolton, R. P., E. V. Lamphere, and M. Menesini, *Laboratory Experiments in Action Chemistry*, New York: Holt, Rinehart and Winston, 1973.

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

Science as Inquiry/
History and Nature of Science

What’s the Evidence?

Item:

Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. Describe how these forms of life are likely to have looked in terms of their physical characteristics.

Answer:

Life in the past occurred in a huge variety of types and sizes. However, essentially the earliest forms of life, the bacteria, are likely to have looked much like the bacteria seen today. Fossil evidence seems to indicate that these were relatively simple organisms consisting of few parts. Many or most were without an identifiable nucleus or other cell organelles other than the cell membrane and the cytoplasm. They were quite small (microscopic) and devoid of any hard body parts. All of these life forms were likely aquatic and probably readily transparent. A few may have had filamentous structures (cilia) extending out from the cell membrane. Others may have had folded membranes and various asymmetrical shapes. Overall, however, they could all be described as very simple organisms in terms of their physical structures.

Science as Inquiry/
History and Nature of Science

Atmospheric Evidence

Item:

Consider the components of the Earth's earliest atmosphere and the life forms that the fossil evidence tells us seem to have been the first to appear. Which of the following statements is true?

A. The evolution of life caused dramatic changes in the composition of the Earth's atmosphere, which did not originally contain oxygen.

B. The evolution of life occurred only because of the Earth's rich oxygen-atmosphere, not found on any other planet.

C. Early life forms were very different from life today and did not have any use or need for the element oxygen.

D. Bacteria, which require an oxygen-atmosphere, are likely to have evolved much later than green plants so that the plants had time to enrich the atmosphere with oxygen in order for the bacteria to survive.

Justification:

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

Answer:

A. Certain rock forms (such as red beds and carbonates) provide evidence that the earliest atmosphere of Earth had very little or no oxygen. Many of the earliest life forms, in fact, resemble simple bacteria found today. Based on the available fossil evidence, it seems that life evolved from simple to complex forms, and that the process of photosynthesis carried out by some bacteria and the early algae was principally responsible for the Earth's oxygen.

History and Nature of Science

It's All in the Fossils

Item:

As you know, fossils are the key to knowing how areas of the Earth have changed and how life evolved. What do fossils tell us about the evolution of life forms?

A. After a relatively short time, the ancient invertebrate life forms were quickly overcome and replaced by abundant, diverse forms of invertebrates.

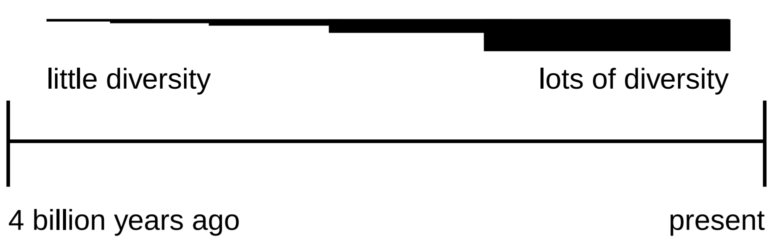
B. Abundant and diverse forms of both vertebrates and invertebrates evolved simultaneously during the Pre-Cambrian Era (over 600 million years ago).

C. Plants were the first life forms to evolve because no other life was possible until the oxygen given off by plants by the process of photosynthesis filled the atmosphere.

D. Life first appeared as simple forms over 3.5 billion years ago and evolved slowly with great bursts of diversity seen during the Cambrian Period (approximately 570 million years ago).

Justification:

Create a timeline beginning 4 billion years ago up to the present. Draw a bar over your timeline to show the relative amount of diversity of living things at each time period. The thicker the bar, the greater number of life forms present at that time. For example:



Answer:

D. The Pre-Cambrian/Cambrian boundary (about 600 million years ago) is distinguished by a burst of life resulting in an abundance of living things with great diversity. Therefore, the student's timeline illustration should show a narrow bar suddenly becoming quite thick. Do not worry too much about whether the timeline is drawn to scale—the concern here is that the students acknowledge the burst of life that apparently occurred at the Pre-Cambrian/Cambrian boundary.

History and Nature of Science

Cut Off in Time, 1

Item:

What is a mass extinction? Describe the history of mass extinction of life forms on Earth.

Answer:

A mass extinction is when up to 90% of all existing species world-wide become extinct relatively suddenly. Fossil and geologic evidence indicates that mass extinctions occurred five different times: 440 million years ago (mya), 365 mya, 250 mya, 215 mya, and 68 mya—all dates are approximate.

Science as Inquiry/
History and Nature of Science

Cut Off in Time, 2

Item:

Consider the history of mass extinctions of life on Earth. Discuss several possible causes for each or all of these events.

Answer:

The decline of any species usually has multiple causes. Be wary of students asserting that any one simple circumstance or event (e.g., volcanic eruption) was the (only) cause of a world-wide mass extinction. Students may discuss any of the theories presented in the readings that go with this Micro-unit, or construct and present a novel one of their own. In any case, proposed causes should be supported by data and/or evidence found in the fossil/geologic record.

Consumables

Item	Quantity (per lab group)	Activity
bromthylmol blue indicator	25–50 mL	4
Elodea plant	1	4
fossil kits	10	2
sodium hydroxide, 25 mL	1 M	4
straw, soda type	1	4
students handouts	—	1, 2, 3
water, distilled	200 mL	4

Nonconsumables

Item	Quantity (per lab group)	Activity
beaker, 400-mL	1	4
graduated cylinder, 20–50 mL	1	4
lamp or strong light source, goose-neck high intensity	1	4
ruler, metric	1	1
test tube, 18 mm x 150 mm	5	4
test tube holder	1	4

Key to activities:
1. Pictures from the Past
2. The Plot Thickens
3. Turn Out the Lights, the Party's Over
4. My Life's Work

Activity Sources

Bolton, R. P., E. V. Lamphere, and M. Menesini, *Laboratory Experiments in Action Chemistry*, New York: Holt, Rinehart and Winston, 1973.
Danielson, E. W., and E. J. Denecke, *Earth Science*, New York: Macmillan Publishing Co., 1989.
Futuyma, D. J., *Evolutionary Biology*, 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.
Spaulding, N., *Earth Science*, Lexington, Mass.: D. C. Heath and Co., 1994.
Zihlman, A. L., *The Human Evolution Coloring Book*, Oakville, Calif.: Coloring Concepts, 1982.
Zumberge, J. H., *Elements of Geology*, New York: John Wiley & Sons, Inc., 1959.

Images: Student Activities

Page 8. Univ. of Michigan Museum of Paleontology, images A, B, C, E, F, H; Univ. of Minnesota Paleontological Collection, image D.
Page 9. After Zumberge, J. H., Elements of Geology, New York: John Wiley & Sons, Inc., 1959.

(continued)

Page 10. After von Zittel, Karl A., *Textbook of Paleontology,* New York: The MacMillan Co., 1899.
Page 11. 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.
Page 12. After Colbert, Edwin, *Evolution of the Vertebrates*, New York: John Wiley & Sons, Inc.
Page 13. As appearing in Zumberge, J. H., *Elements of Geology*, New York: John Wiley & Sons, Inc., 1959, from Univ. of Michigan Museum of Paleontology.
Page 14. Arnold, Chester A., *An Introduction to Paleobotany*, New York: McGraw-Hill Book Co., 1947.
Page 15. Futuyma, D. J., *Evolutionary Biology*, 2nd Ed., Suderland, Mass.: Sinauer Associates, 1986.