



*Exploring the World of Science*

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**UNDERSTANDING EARTH HISTORY  
AND  
THE IDENTIFICATION OF FOSSILS**

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# **UNDERSTANDING EARTH HISTORY TO IDENTIFY FOSSILS**

1. Introduction and What Are Fossils?
2. How a Fossil is Formed
3. The Geologic Time Scale
4. Major Groups of Fossils
5. Identification of Fossil Groups
6. Resources
7. Closure and Questions/Answers

## What Are Fossils?

Many of us remember searching for fossils in our backyards at one time with one or more of Mom's old Cool Whip tubs and at the end of the day it would be full of rocks that appeared to have designs or imprints all over them. Then we'd reach for our How and Why Wonder book that told us all about the dinosaurs or plants and animals that may have made those imprints. The fun continues today with a new generation of kids and that's one of the reasons that the Fossils Event returns to Science Olympiad competition.

The word fossil is derived from the Latin *Fossilis* meaning "dug up from the ground". For a long time, the word fossil was applied to just about anything that was dug up from the ground including arrowheads, and even human remains. I'm sure you've also heard the term 'fossil fuels' used to describe hydrocarbon fuels such as coal and petroleum. Coal and petroleum are made up of individual plants that are fossils, but the coal and petroleum themselves are not fossils, so the term 'fossil fuels' then is somewhat misleading. It only implies the millions of years it took to create them.

Today, geologists and paleontologists who study fossils restrict the definition of fossils to include only the naturally preserved remains or traces of plants and animals that lived in the geologic past. The term 'geologic past' has also generated controversy among scientists over the years. Many geologists define the geologic past as simply that period of time before recorded human history. This interpretation of geologic history is limited because there most certainly have been plant and animal species that have appeared and disappeared since the beginning of human civilization- many of which we are even not aware. Other geologists set the dividing line between the past and present at the beginning of the Holocene epoch about 11,000 years ago. This too has its problems in that a measured age cannot be assigned to the rocks containing the fossils being investigated, and there is nothing in the fossilization process that relates to the passage of time.

In any case, the world of fossils is a mysterious and fascinating one. In this presentation, I will provide an overview of Earth's History in a way that can be used to identify different classes of fossils and help students understand other aspects of the study of fossils such as:

- Identification of sedimentary rocks in which fossils may be found
- Conditions necessary for fossilization to occur
- Differentiating between casts and molds
- Evidence of life activities including tracks, trails, burrows and coprolites
- Interpretation of environments: terrestrial, shallow marine, swamp, lake, river, etc.
- Adaptations made to their environment
- Mode of life: filter feeder, predator, scavenger, deposit feeders, swimmer, benthic, pelagic, sessile, vagrant, detritus feeder, primary consumer, etc.
- Evolutionary trends shown by the fossils
- Index fossils
- Relative vs. absolute age
- Sequence events using dating techniques to determine the age of rock layers
- Radiometric dating
- Dinosaur theories: extinction, warm blooded, feathers, behavior, relation to birds

Also, be sure to check the Fossil List for the competition included at the end of this presentation as well as the specimen kit available from Earth Science Educators Supply. The recommended reference for the Fossils Event is *The Audubon Society Field Guide to North American Fossils*. Refer to the order form in the Science Olympiad Coaches Manual.

## How a Fossil is Formed

Imagine creatures walking through a prehistoric forest. As they lumber along the muddy edge of a river, they stop for a drink. Then suddenly, a rain of volcanic ash covers the forest and fills the footprints. Over time, this mud hardens into rock and for a million years the footprints are buried under this volcanic ash. This, in the folklore of fossils is known as a *trace fossil* because it only provides evidence of the animal's activity.

Most fossils (over 90%) are formed from sedimentary rock. Most fossils could not withstand the searing heat associated with igneous rock formation, or the rigorous physical and chemical changes wrought on metamorphic rocks below the Earth's surface.

Fossils are formed in a variety of ways. In some cases, the entire organism is preserved such as insects trapped in amber or mammals that are frozen in ice. But in most cases, the soft parts of the plant or animal are destroyed over time, leaving little or no evidence. What remains are the hard parts of the organism that were buried quickly, thus preserving them from decay. Most of the fossils used to interpret the Earth's history and reconstruct ancient environments are therefore of organisms whose hard parts such as teeth, shells, or bones are preserved. The alteration of fossilized bones or shells that give us direct evidence of an organism's presence can be grouped into one of these three categories:

### Permineralization

The original porous hard components such as bone are preserved, but some secondary intercellular mineral matter is added over time. This includes most vertebrate bones and invertebrate shells.

### Replacement

In replacement, secondary mineral matter which gradually seeps into the organism from the surrounding matrix and then replaces the original organic tissue in an almost atom for atom matter. The result is a near perfect replica of the organism. One example would be petrified wood. Another example is that of silicified and agatized Permian fauna found in West Texas.

### Recrystallization

In this process, the fine-grained original material of the hard parts of organisms is just reorganized into larger crystals of the same material. No new material is either added or taken away and therefore there is no alteration in the external form of the hardened parts.

There are other ways to indicate the presence of an organism including the following:

### Carbonization (also known as Distillation)

Leaves in some cases can be preserved as carbon films on the surface of rock after the organic components of the leaf containing oxygen, carbon, and hydrogen have burned off during the process of decay. A more stable form of carbon remains leaving an exact shape and venation of the leaf. Some animal fossils may also be preserved this way, but the impression left is not that of carbon.

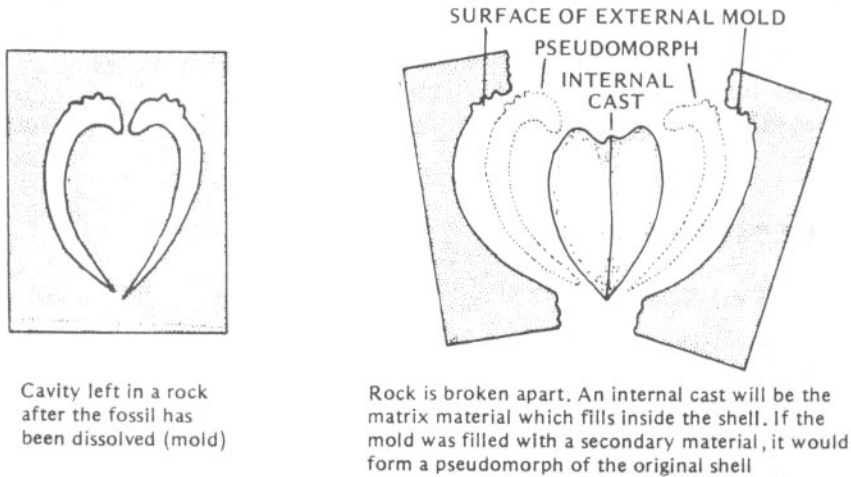
### Desiccation

Desiccation is the 'driving off' of water from animal tissue. The bodies of some Native-Americans living in North and South America some 10,000 years ago were found to be preserved in their entirety using this method.

More often than not, all we are left with is less direct evidence of an organism's presence. Indirect fossil evidence includes:

### Molds, Casts and Imprints

Given time- and in geologic history there's lots of that- even the hard shells and bones of an organism may dissolve. When the shell or bone has been buried in sand or mud, the sediment around it will harden. When the shell or bone dissolves, it leaves a cavity in the rock called a *mold*. The outside of a shell leaves an imprint called an *external mold*, while the imprint of the inside of the shell is the *internal mold*. The drawing of the fossil cavity below provides an example.



### Steinkerns

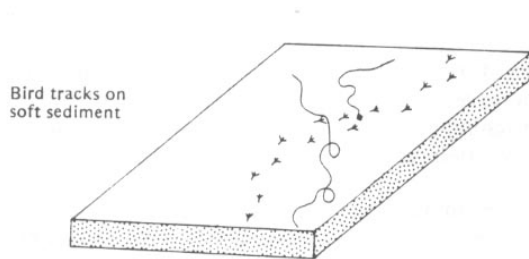
If the interior of a shell fills with mud that hardens and then becomes free of the surrounding matrix, the internal mold that results is called a *Steinkern*. Because the steinkern is formed in the interior of a shell, it does not show the outer form or surface features. Steinkerns from snails are common. Bivalves and brachiopods may also be preserved in this fashion.

### Casts

If the cavity left by the whole shell has filled with a mineral such as calcite, silica, or pyrite- the result is often termed a natural cast.

### Trace Fossils

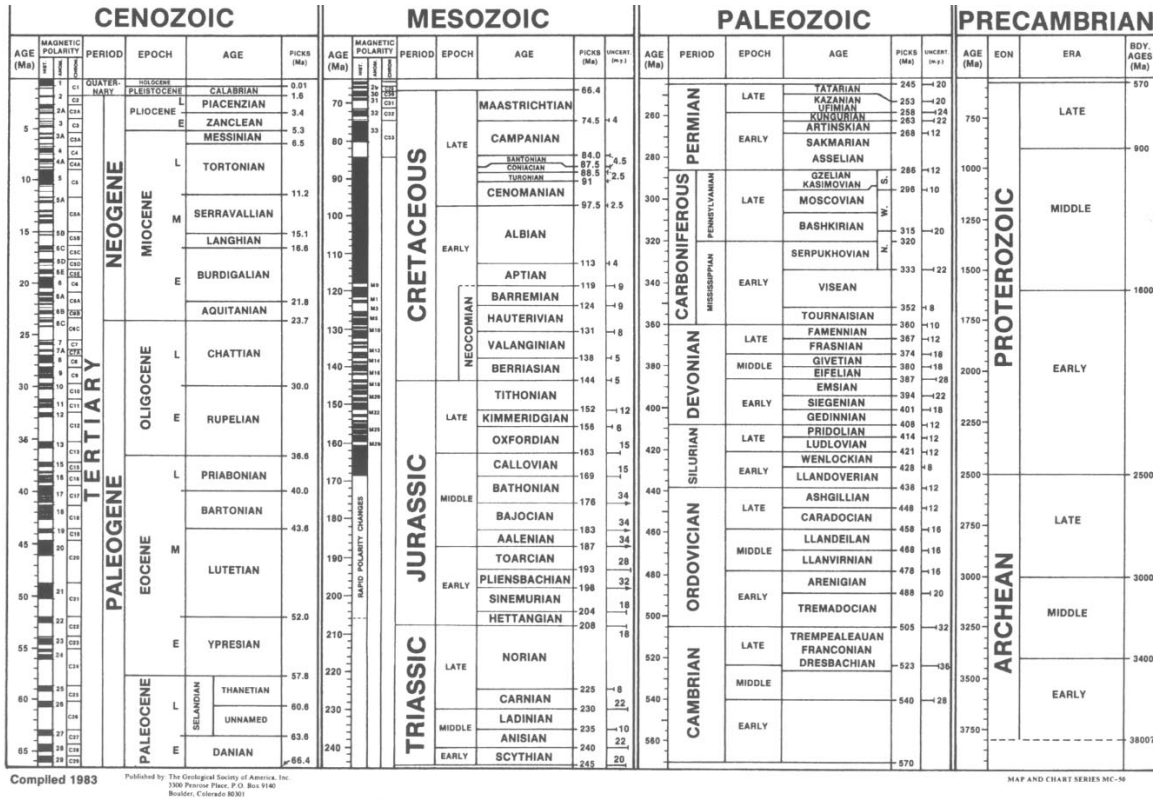
Trace fossils refer to anything that is not a part of the organism itself yet provides credible evidence of its presence or its activities. Trace fossils may include bird tracks (as shown in the drawing to the left) and dinosaur tracks. Chemical residue such as traces of organic acids is particularly useful in studying many Cambrian and Precambrian fossils. *Corpolites*- the fossilized fecal material of ancient animals may also contain the remains of partially digested foods giving us information about the ecology of the animal.



### The Geologic Time Scale

Geologists and most of the rest of us by now know that the Earth has been around for a very long time- at least 3.4 billion years. In that time, life evolved from very simple one-celled organisms to the complex array of life forms that are with us today. Fossils tell the story of this long and continuing saga as well as environmental changes that may have influenced this evolution. Therefore, an understanding of the Geologic Time Scale and its benchmarks will give you a much better understanding of the predominant life forms that existed during each phase. The drawing below from the Geological Society of America will give you a quick overview.

# Earth History Overview

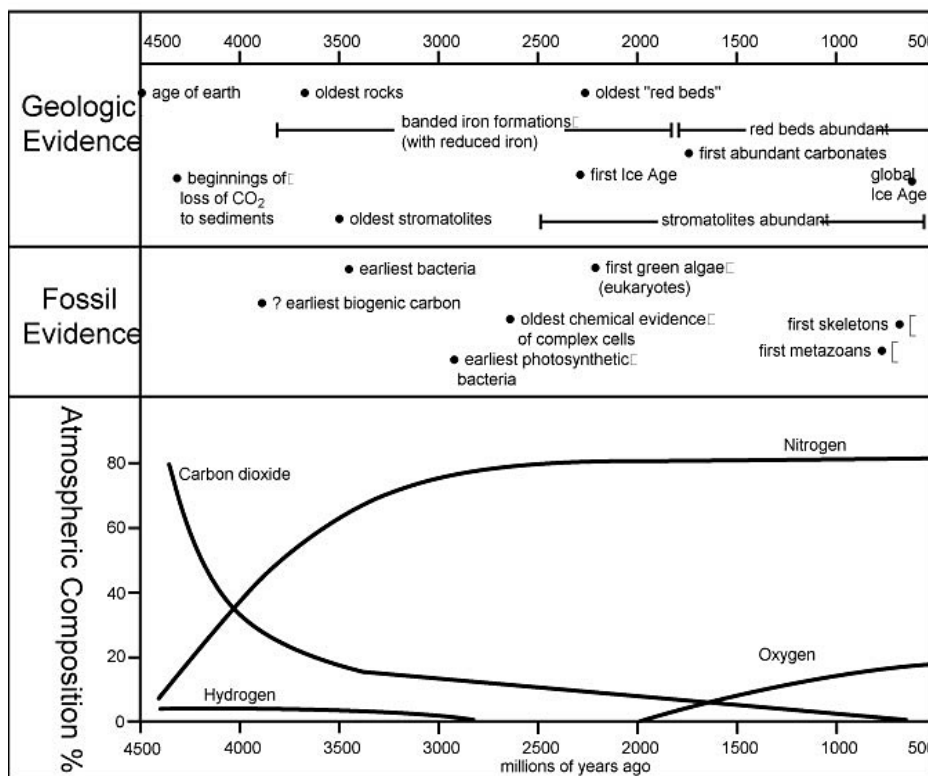


Decade of North American Geology. (Courtesy of the Geological Society of America, Inc.)

You begin reading the chart upward from the bottom right corner to the top of the Precambrian column. Then begin at the bottom of the Paleozoic column to the left and read upward. Do the same for the remaining two columns. Geologic time is divided into basic units known as Eons, Eras, Periods, and Epochs, with each characterized by different environmental conditions and by the specific kinds of living things that flourished in them. Thus an understanding of geologic history will enhance your understanding of why certain organisms flourished during certain periods of the Earth's history, why others perished, and what adaptations were made by others to cope with what were often sudden and catastrophic ecological changes.

## Geologic Time Division

All of geologic time is divided into two Eons- the Precambrian that begins with the formation of the Earth some 3.4 billion years ago and ends when fossils became abundant in rocks some 570 million years ago. That's one hombre of a long time and inconceivable to most. Until recently, the Precambrian era was considered the doldrums of geologic history. Yet we now know that very significant changes in the chemical and atmospheric makeup of the primordial Earth were taking place at this time. As volcanoes spewed carbon dioxide forth from their craters, this encouraged the development of weather systems causing rain to fill in the valleys and gorges. The proliferation of freestanding water on the surface of the planet would be essential to the development of life. The diagram below shows geologic and fossil evidence as well as atmospheric change during the Precambrian Eon.



Modified from figure 17.1 The Earth's Atmosphere, p. 276, Chapter 17 Atmosphere, Water & Weather by P. Brimblecombe and T.D. Davies, in The Cambridge Encyclopedia of Earth Sciences, David G. Smith, edit Cambridge University Press, 1981, 496pp.

The second Eon, the Phanerozoic, began with the close of the Precambrian and continues to the present day. The Phanerozoic in turn is divided into three Eras- the Paleozoic, Mesozoic, and Cenozoic.

The three Eras are in turn divided into **Periods** as follows:

**Paleozoic**

- Cambrian
- Ordovician
- Silurian
- Devonian
- Mississippian
- Pennsylvanian
- Permian

**Mesozoic**

- Triassic
- Jurassic
- Cretaceous

**Cenozoic**

- Tertiary
- Quaternary

All of these Periods are then divided into Epochs. The Paleozoic and Mesozoic Periods are simply divided into "Early," "Middle," and "Late" Epochs, while the Epochs of the Cenozoic Era are given distinctive names. The five Epochs of the Tertiary Period are the Paleocene, Eocene, Oligocene, Miocene and Pliocene. The two Epochs of the Quaternary Period are the Pleistocene and the more recent Holocene.

Fossil-bearing rocks are given the same names as the geologic periods they represent. For example, all rocks of the Cambrian Period are called the Cambrian System. Those of the Early, Middle, and Late Cambrian Epochs would make up the Lower, Middle, and Upper Cambrian Series respectively.

Now let's briefly list the major fossil groups to be included in the Science Olympiad Fossil competition before we assign them their respective place in Earth's geologic history.

**Fossils to be used in the Science Olympiad Fossil Competition**

In the Science Olympiad Fossils competition, participants will identify select fossils representing a limited number of phyla, classes and genera (Genus:). Specimens will not be identified at the species level. The Fossil List for the 2003 competition (subject to change) is given below.

## 2005 FOSSIL LIST

### PROTISTA

Genus: Foraminifera  
Order: Fusulinida\*  
Genus: Nummulites

### ANIMALIA

#### Phylum: Porifera

Genus: *Astraeospongia*  
Genus: *Cliona*  
(Sponge borings)

#### Phylum: Cnidaria

Subclass: Rugosa  
(horn coral\*)  
Genus: *Hexagonaria*  
Subclass: Tabulata  
Genus: *Favosites*\*  
Genus: *Halysites*

#### Phylum: Bryozoa

Genus: *Archimedes*\*  
Genus: *Rhombopora*\*

#### Phylum: Brachiopoda

Class: Inarticulata  
Genus: *Lingula*  
Class: Articulata  
Genus: *Composita*\*  
Genus: *Rafinesquina*  
Genus: *Atrypa*\*  
Genus: *Mucrospirifer*\*  
Genus: *Juresania*  
Genus: *Platystrophia*  
Genus: *Leptaena*

#### Phylum: Mollusca

Class: Gastropoda  
Genus: *Turritella*\*  
Genus: *Worthenia*\*  
Genus: *Bellerophon*  
Genus: *Conus*  
Class: Bivalvia  
Genus: *Exogyra*\*  
Genus: *Gryphaea*\*  
Genus: *Pecten*  
Genus: *Nucula*  
(Clams, mussels,  
oysters)  
Class: Cephalopoda  
Order: Nautilida (Nautilus)  
Order: Ammonitida  
(*Ammonite*\*/*Baculites*\*)

Order: Belemnitida  
(Belemnite)  
Order: Orthocerida  
(Orthoceras)

#### Phylum Arthropoda

Class: Trilobita  
Genus: *Elrathia*\*  
Genus: *Cryptolithus*  
Genus: *Phacops*  
Class: Crustacea  
Class: Insecta  
Class: Arachnida

#### Phylum: Echinodermata

Class: Blastoidea  
Genus: *Pentremites*\*  
Class: Crinoidea  
(Crinoid stems\*, calyxes)  
Class: Echinoidea (urchins\*,  
sea biscuits, sand dollars)  
Class: Stellerioidea  
(starfish, brittle stars)

#### Phylum: Chordata

Subphylum: Hemichordata  
Class: Graptolithina  
(Graptolites)  
Subphylum: Vertebrata  
Class: Osteichthyes  
(Bony fish\*)  
Class: Chondrichthyes  
(Cartilaginous fish/  
Shark teeth\*)

#### Class Reptilia

Dinosaurs:  
Genus: *Allosaurus*  
Genus: *Apatosaurus*  
Genus: *Brachiosaurus*  
Genus: ***Carnotaurus***  
Genus: *Corythosaurus*  
Genus: *Iguanodon*  
Genus: *Plateosaurus*  
Genus: *Stegosaurus*  
Genus: *Triceratops*  
Genus: *Tyrannosaurus rex*  
Dinosaur Bone \*  
Link: Therapsid (mammals)  
Link: Archaeopteryx (birds)

#### Plantae

**Genus: Stromatolites**

**Genus: Annularia-**  
**Calamites**  
**Genus: Lepidodendron**  
**Genus: Medullosa**  
**Genus: Cycadoidea**  
**Genus: Metasequoia**  
**Genus: Platanus**  
**Grasses (No genus**  
**selected)**

#### Fossil Bearing Rocks

Shale  
Mudstone  
Siltstone  
Limestone  
Chalk  
Coquina  
Sandstone  
Coal

#### Fossil Evidence

Amber  
Coprolite  
**Internal/external molds**  
Petrified wood\*  
Carbon traces

\*Specimens marked with an asterisk are included in a kit distributed by **ESES**, Box 503, Lee's Summit, MO 64063. Cost is \$16 per kit. Phone 816-524-5635. **The Audubon Society Field Guide to North American Fossils**, may be purchased at a discount. Refer to the NSO Coaches Manual or <http://www.soinc.org>



## Classification of Fossils

A review of the Binomial Nomenclature system used to classify living things might be in order at this time. All living things are divided into one of five Kingdoms of living things including Monera (bacteria, blue green algae, other prokaryotes); Protista (Protists); Fungi (molds, mushrooms); Plants and Animals. All kingdoms in turn are divided into the following subgroups from largest to the most specific in the order listed:

- Phylum
- Class
- Order
- Family
- Genus
- Species

Housecat	
<b>Kingdom</b>	<b>Animal</b>
<b>Phylum</b>	<b>Chordate</b>
<b>Class</b>	<b>Mammal</b>
<b>Order</b>	<b>Carnivore</b>
<b>Family</b>	<b>Felidae</b>
<b>Genus</b>	<b>Felis</b>
<b>Species</b>	<b>domesticus</b>

The example to the right shows how a housecat would be classified using the Binomial classification system. In the Fossils competition, you will only be responsible for knowing up to and including the Genus listed for each sample.

## Overview of Each Geologic Period and Major Fossil Groups

### Precambrian Eon

The first evidence of life is found in rocks approximately 3.4 billion years old. Bacteria and blue-green algae are examples of prokaryote life forms common to this Eon. Prokaryote cells have no nucleus or organelles making them different from advanced life forms such as plants and animals with eukaryotic cells. In the early Precambrian, nutrients would most likely have been formed spontaneously from compounds in the atmosphere and ocean such as methane, ammonia and carbon dioxide. With less oxygen in the atmosphere, these compounds could not be oxidized and would then accumulate over time.

**During the late Precambrian Eon the first advanced cells began to appear about 1-1.4 billion years ago. The first multicellular plants and animals including sponges and stromatolites appeared about 1 billion years ago. Sponges, jellyfish, cnidarian, annelids and primitive arthropods begin to appear and diversify.**

### Phanerozoic Eon

#### Paleozoic Era

##### Cambrian Period

**500-570 Million Years Ago**

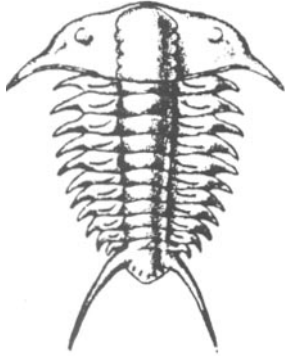
During the Cambrian Period, much of the land was barren as it had been since the origin of the Earth. Life would only move out of the water when atmospheric oxygen levels were high enough to develop a layer of ozone that could protect the Earth's surface from radiation. The climate of the Cambrian is not well known. It was probably not very hot, nor very cold. Life on Earth would remain in the moderation of water until the Ordovician Period which would follow.

**Trilobites were the dominant life form of the Cambrian Period. These segmented, three lobed animals had calcified skeletons and were preserved in a variety of rock types.**

Trilobites may be termed an Index Fossil. An Index Fossil-usually an animal fossil is used to:

- Determine the relative geologic age of a sediment
- The nature of paleoenvironments
- The paleogeography that characterized a particular area

To be considered an Index Fossil (as Trilobites are), a fossil must meet the following three conditions:



1. The organism should have lived during a relatively short period of geologic time- but have been abundant in number during that time.
2. The organism should have a wide geographic distribution
3. The organism should have a distinctive morphology and appearance.

During the Cambrian Period, the first radiolarians, stromatoporphs, gastropods, bivalves, cephalopods, ostracodes, brachiopods, cystoids, graptolites and conodonts appeared.

### **Ordovician Period                      430-500 Million Years Ago**

During the Cambrian Period, the continents were widely separated by deep oceans similar to the way they are today. As time went on, the oceans became smaller as the continents moved closer together. The Cambrian ended with the mass extinction of almost 75% of trilobite families and half of all sponges (Porifera), as well as many gastropods and brachiopods. Perhaps this extinction was caused by falling water levels that disrupted life in shallow waters.

Mild climates probably covered much of the world during the Ordovician Period. Most Ordovician rocks are rich in fossils that herald the appearance of the first rugose and tabulate corals, eurypterids, bryozoans, crinoids, starfishes and jawless fishes.

### **Silurian Period                              395-430 Million Years Ago**

The Ordovician Period ended with another mass extinction with about 25% of all existing families perishing, with the remaining Trilobites losing 50% of their families.

Trilobites were still locally abundant, though on the decline. The first land plants, blastoids and jawed fishes appeared during the Silurian.

### **Devonian Period                              345-395 Million Years Ago**

Generally dry conditions flourished across much of North America, Siberia, China, and Australia during the early Devonian Period. Coals began to accumulate as land plants flourished in the equatorial belt by the mid-Devonian. Warm, shallow seas covered much of North America at that time. By the late Devonian, the supercontinent Pangea would begin to assemble.

Land plants, sponges, corals, brachiopods, sharks and bony fishes were abundant during the Devonian Period. The first ammonoids, arachnids, sharks, bony fishes and amphibians appeared.

### **Mississippian Period                      325-345 Million Years Ago**

The Mississippian Period was relatively short- only about 20 million years and along with the Pennsylvanian Periods include the "Carboniferous Period" marked by the formation of lush, swampy forests- the fossils of which, would later become the vast coal deposits of eastern and central North America.

**The Mississippian Period is the age of Crinoids and blastoids. Crinoids are filter feeders needing warm water to produce their skeletons. Foraminiferans and bryozoans were also abundant. The first seed ferns and belemnoids also appeared during the Mississippian.**

### **Pennsylvanian Period            280-325 Million Years Ago**

The Pennsylvanian was a period of mountain building as continents continued to move together completing Pangea. The loss of warm shallow seas would dramatically change marine life. The crinoids declined as did the fenestrate bryozoans.

**The Pennsylvanian is probably best noted for the large coal swamps which included the lycopods or scale trees- some reaching heights of 100 feet. Sphenophytes and ferns were also abundant. Cordiates with broad leaves instead of needles also began to appear, as did many species of terrestrial insects, amphibians and reptiles, The distinguishing characteristic of reptile fossils includes the development of the amniote egg with a strong watertight covering that surrounded the yolk.**

### **Permian Period                    225-280 Million Years Ago**

The Permian marks the end of the Paleozoic Era with the extinction of 99% of all life at its end. This mass extinction included rugose corals, trilobites, eurypterids and blastoids. Many ammonoids, bryozoans, brachiopods, crinoids, amphibians and reptiles were severely decimated.

**During the Permian Period, foraminiferans, ammonoids, insects, bryozoans, productid brachiopods and reptiles were abundant. The first cycads and mammal like reptiles also appeared.**

## **Mesozoic Era**

### **Triassic Period                    190-225 Million Years Ago**

The mass extinctions at the end of the Permian were so severe that many different life forms began to appear at the beginning of the Triassic Period. There was very little marine life left at the beginning of the Triassic. The ammonoids had barely survived the Permian extinction, but later in the Triassic would diversify to over 400 genera. Most other surviving invertebrate groups also recovered except for the brachiopods. One of the first new reptiles to appear in the early Triassic was the Thecodonts, which were small lizardlike meat eaters and the ancestors of dinosaurs, crocodiles and birds.

**During the Triassic, the first dinosaurs appeared. They were predominately saurischians who were bipedal with short forelimbs and stabbing teeth. Lizards and turtle also originated in the Triassic as did Ichthyosaurs and Plesiosaurs (marine reptiles).**

### **Jurassic Period                    136-190 Million Years Ago**

Considered the golden age of the dinosaurs, the Jurassic was characterized by a mild, warm climate as the North American continent lay further to the south than it does today. Worldwide, many coal deposits also formed during this period. Sea level was low, but rising and the super continent **Pangea began to break up.**

Cycads, conifers, ammonoids, belemnoids, and dinosaurs were abundant during the Jurassic Period. The Period also saw the first Pterosaurs or flying dinosaurs appear as well as early forms of birds and mammals.

### **Cretaceous Period                      65 –136 Million Years Ago**

The Cretaceous Period has the distinction of having more rocks than any other period. This is due to a number of factors. As a more recent period, there has been less time for erosion to remove these rocks than those from other periods. The Cretaceous also lasted longer than most periods- some 70 million years and the seas at that time also stood higher on the continents allowing thick deposits to be laid down. This is probably due to the more rapid movement of continental plates from one another causing the areas where they separate to become high ocean ridges displacing more water on to the continents.

**The Cretaceous saw the end of the dinosaurs, ammonoids, belemnoids, flying and marine reptiles. During the Period however, angiosperms, scleractinian corals, gastropods, bivalves, bryozoans, and dinosaurs were abundant. The first flowering plants (angiosperms) and primates appeared during the Cretaceous. The mass extinction of dinosaurs, corals, crinoids, and foraminiferans may have been due to the impact of a large meteorite, whose impact would have led to a deterioration of the climate following the ejection of dust into the atmosphere, blocking sunlight and destroying the food supply.**

The Cenozoic Era is not covered extensively in the Fossils competition, but will be mentioned here briefly.

### **Cenozoic Era**

#### **Tertiary Period                      1.8-65 Million Years Ago**

The Tertiary Period is regarded as the age of mammals. The first mammals to appear in the Tertiary were small with correspondingly small brains. Many had five toes on each foot and walked on their soles. Teeth became more specialized for predation as well. Other groups also appeared including the first horse during the Eocene Epoch. Carnivores appeared during the Paleocene, elephants during the Oligocene and Hominids (man) during the Miocene.

#### **Quaternary Period                      Present-1.8 Million Years Ago**

The Quaternary is divided into two Epochs, the Pleistocene and the more recent Holocene. The beginning of the Pleistocene is characterized by the start of a cooling trend about 1.8 million years ago that resulted in four glacial periods that ended about 11,000 years ago. During this period, the first *Homo sapiens* **appeared and human civilization began.**

**If nothing else, you should be in awe of the amount of time that it has taken for life to develop on Earth, and that civilized man would probably have appeared sometime after 11:59PM if the Earth's history were recorded on a 24-hour clock**

### **Using a Taxonomic Key to Identify Fossils**

One of the great things about this event is that it includes a lot of biological science process skills as well as those of Earth Science. One thing that you can do to familiarize students with different fossil groups is to use taxonomic keys to identify the major groups. Taxonomic keys can be used as an individual tutorial, cooperative workgroup or station-to-station activity. Once students gain proficiency, you can also have them create their own taxonomic keys as they practice this event with their team, or for classroom use. Follow the directions given below and fill out the answer sheet provided by the Presenter who will review answers with you upon completion.

## KEY TO IDENTIFICATION OF THE MAJOR FOSSIL PHYLA

To use this key, start with the first statement. If the fossil in question is colonial, go to statements 16, 17, 18, and 19. If the fossil is not colonial, go to statement 2. Follow the directions given in the subsequent statements containing characteristics of the group being investigated. Eventually the key will lead to the proper name for the phylum to which the fossil belongs. For your convenience, definitions and sample illustrations are provided.

1. Colonial—go to 16, 17, 18, or 19



Animals that live in close association with others and usually cannot live as separate individuals (many grow as an attached group)

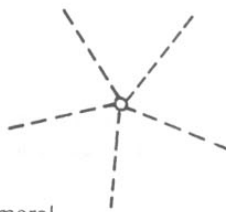
2. Non-colonial (solitary)—go to 3, 4, 5a, or 5b. If none of these, go to 7, 10, or 13.



Usually refers to an organism that lives as an individual and not as part of a colony

Non-colonial (solitary)

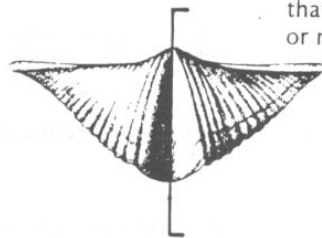
3. Pentamerous symmetry—go to 14 or 15



Arrangement of the organs or shape gives the organism a five-rayed appearance (like a starfish)

Pentamerous

4. Bilateral symmetry—go to 6, 7, 8, 9, or 10



Arrangement of the organs or shape of an organism such that when divided in half the opposite sides share equal or mirror images

Bilateral

- 5a. Coiled in a *nonchambered* (hollow) cone-shaped spiral (conispiral) or flat-coiled spiral (planispiral) shell

Phylum Mollusca

Class Gastropoda (snails)

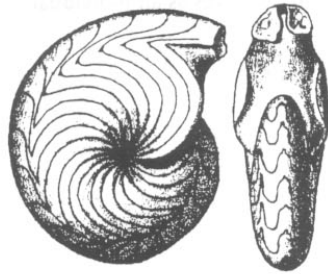


Coiling of whorls in a cone-shaped spire and not in a single plane

Cone-shaped Spiral

5b. Coiled in a planispiral manner without sutures—go to 6

6. Coiled in a planispiral manner *with* suture markings on shell—go to 13

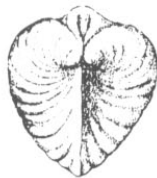


Coiling of whorls in a single plane

Planispiral Coiled

7. Cigarlike shape—go to 13

8. Bivalved—go to 11 or 12



Similar



Dissimilar

A bivalved animal is one that has a shell composed of two equal or nearly equal valves that can open and shut

9. Trilobed, chitin-covered, insectlike organism: many segments in between visible head and tail  
 Phylum Arthropoda  
 Class Trilobita (trilobites) (pp. 69-70)
10. Cup- or horn-shaped mass with many vertical partitions (septa) radially projecting inward into the life cavity  
 Phylum Coelenterata (cnidaria) (solitary corals) (pp. 56-58)
11. Two valves (shells) similar and mirror images; crenulations or other teeth along hinge line on inside; no opening near beak  
 Phylum Mollusca  
 Class Bivalvia (pelecypods) (clams, oysters, etc.) (pp. 61-63)
12. Two valves dissimilar; plane of symmetry is through middle of shell, perpendicular to hinge line; pedicle opening near beak for fleshy stalk used for attachment  
 Phylum Brachiopoda (brachiopods) (pp. 58-60)
13. Straight partitions within life cavity; straight, cigarlike with radiating crystals (belemnites)  
 Phylum Mollusca  
 Class Cephalopoda (pp. 61, 64-66)
14. A stem attachment or fragments of a stem; body cavity covered by calcareous plates; attachments for arms at top of body cavity (assuming the fossil is not deformed)  
 Phylum Echinodermata  
 Attached types (crinoids, cystoids, blastoids) (pp. 66-69)

15. No stem or stem attachment visible; no calcareous arms as in 14, globular or disklike  
Phylum Echinodermata  
Unattached types (starfish, sea urchins, etc.) (pp. 66-69)
16. No visible divisions for individual's life cavities; usually appears as an irregular mass (or with slight radial symmetry) with spicules or lines of spicules visible  
Phylum Porifera (sponges) (p. 55)
17. Microscopic (or at least very small) openings in large calcareous mass; no septa in these life cavities  
Phylum Bryozoa (p. 56)
18. Larger openings (larger than one millimeter), touching or separated, distributed over a colonial mass; vertical partitions (septa) radially projecting inward dividing the life cavity  
Phylum Coelenterata (cnidaria) (colonial corals) (pp. 56-58)
19. Usually as thin carbonaceous films in black shale; long, narrow, or interconnecting colonies, with microscopic (or very small) cavities for individuals  
Phylum Hemichordata (graptolites) (p. 71)

## Resources for Fossils

Fossil Kit available from Earth Science Educator's Supply  
P.O. Box 503  
Lee's Summit, MO 64063  
(816)-524-5635  
The cost of the kit is \$16.00

*The Audubon Society Field Guide to North American Fossils*  
Can be purchased at a discount from National Science Olympiad  
Check your Coaches manual Order Form

<http://pubs.usgs.gov/gip/fossils/intro.html> \* <http://pubs.usgs.gov/gip/dinosaurs/> \*  
<http://www.ucmp.berkeley.edu/help/timeform.html> \*  
<http://www.ucmp.berkeley.edu/help/taxaform.html>  
<http://interactive2.usgs.gov/learningweb/teachers/geoage.htm>  
<http://pubs.usgs.gov/gip/geotime/contents.html>  
<http://www.sciencecourseware.com/VirtualDating/>  
<http://www.bbc.co.uk/education/rocks/flash/indexfull.html>  
<http://www.soinc.org/linksb.htm>  
<http://www.scotese.com/earth.htm>