Paleo Lab 06 - The Cambrian Explosion of Life

An Introduction to Index Fossils

CLASSIFICATION AND TAXONOMY

Geologists follow the lead of biologists in the classification and naming of organisms (taxonomy after taxon = name). Since its introduction early in the 18th century, the system devised by Linnaeus has been used to categorize organisms and to affix a formal name to each species. Major classification categories or groupings are listed below on the left with an example using the species of the common house cat to show how the system may be used:

KINGDOM	Animalia
PHYLUM	Chordata
CLASS	Mammalia
ORDER	Carnivora
FAMILY	Felidae
GENUS	*Felis*
SPECIES	*domestica*

The basic unit of the system is the species, and each category above it includes the divisions below. A two part (binomial) formal designation for each species, following the scheme of Linnaeus, is composed of the capitalized name of the genus (plural = genera) followed by the uncapitalized name of the species (plural = species). Note that the binomial is printed in a special way (italics) to distinguish it.

After at least 5000 years of domestication, man has drawn out of that species such a variety of traits through selection and cross-breeding that it may be more difficult to realize that all such cats belong to the same species than it is to recognize that they share the same genus with the lion (*Felis leo*), leopard (*Felis pardus*), jaguar (*Felis onca*), tiger (*Felis tigris*), and the cougar or puma (*Felis concolor*). All wildcats belong to the same genus but are classified in three separate species found in Europe, Africa, and the Americas (the ocelot), *Felis sylvestris, F. ocreta, and F. pardalis*, respectively.

Panthers, lynxes (bobcats), and cheetahs are assigned to other genera within the family of cats (Felidae) which along with dogs, hyenas, bears, raccoons, badgers, skunks, otters, seals, and walruses assigned to other families constitute the Carnivora, the order of flesh-eating mammals. All these animals share with humans the production of milk, hair on the skin, a single bone lower jaw, differentiated and specialized teeth, and a highly developed brain, features which distinguish members of the Class Mammalia from those in other classes in the Phylum Chordata.

Improvement in knowledge through advancements in instruments for study has shown, furthermore, the limitations of the original two kingdom (animal and plant) concept of Linnaeus. Biologists now use a five kingdom division tabularized below:

Body Composition	Kingdom Designation	Cellular Organization
unicellular	Bacteria	procaryotic
unicellular	Protista	eucaryotic
multicellular	Fungi	eucaryotic
multicellular	Plantae	eucaryotic
multicellular	Animalia	eucaryotic

Organisms with procaryotic cellular organization lack the internal membranes within their cells which define such parts as the nucleus. The single-celled bacteria and blue-green algae comprise the Kingdom Bacteria whereas the other four kingdoms contain either single-celled or many-celled organisms with eucaryotic cellular organization, that is, the presence of internal membranes within cells.

The five kingdoms are unequally represented in the fossil record. Obviously, organisms with mineralized parts such as bones and shells would be expected to have higher representation. However, remains of organic-walled monerans and protistans have been recovered from the oldest rocks containing fossils.

Considering the modes of fossilization outlined in the previous laboratory exercise, the remains.of organisms which lived in shallow marine environments near the margins of continents are best represented in the fossil record. For this reason, major contributors among the phyla listed below will be emphasized in this exercise:

Linnaeus 1735	Haeckel 1866	Chatton 1925	Copeland 1938	Whittaker 1969	Woese et al. 1977	Woese et al. 1990	Cavalier-Smith 1993	Cavalier-Smith 1998
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains	8 kingdoms	6 kingdoms
(not treated)	Protista	Prokaryota	Monera	Monera	Eubacteria	Bacteria	Eubacteria	Bacteria
					Archaebacteria	Archaea	Archaebacteria	
		Eukaryota	Protista	Protista	Protista	Eucarya	Archezoa	Protozoa
							Protozoa	
							Chromista	Chromista
Vegetabilia	Plantae		Plantae	Plantae	Plantae		Plantae	Plantae
				Fungi	Fungi		Fungi	Fungi
Animalia	Animalia		Animalia	Animalia	Animalia		Animalia	Animalia

How LIFE has been classified in the past.

Classification Of Major Biological Groups Commonly Represented By Fossils

KINGDOM BACTERIA
- bacteria
- blue-green algae (Stromatolites)

KINGDOM PROTISTA
- Phylum Protozoa
  - Class Sarcodina-“amoebas”
  - Order Foraminiferida-marine amoebas mostly with calcite skeletons
  - Order Radiolaria-marine amoebas with opal skeletons

KINGDOM FUNGI - the fungi

KINGDOM PLANTAE - the plant kingdom
- “algae” — several groups of aquatic plants, some of which secrete calcite or aragonite skeletons
- * Phylum Bryophyta-the mosses and liverworts
- Phylum Tracheophyta-the vascular or principal land plants

* botanists use the term “division” for this rank

KINGDOM ANIMALIA - the animal kingdom
- Phylum Porifera — the sponges
- Phylum Cnidaria
  - Class Scyphozoa — the jellyfish
  - Class Anthozoa — the corals
    - Order Rugosa
    - Order Tabulata
    - Order Scleractinia
- Phylum Bryozoa — the bryozoans or “moss” animals
- Phylum Brachiopoda — the “lamp shells”
  - Class Inarticulata — brachiopods with unhinged valves
  - Class Articulata — brachiopods with hinged valves
- Phylum Mollusca — the mollusks
  - Class Gastropoda — the snails
  - Class Pelecypoda (Bivalvia) — the clams
  - Class Cephalopoda
    - Subclass Nautiloidea
    - Subclass Ammonoidea
    - Subclass Coleoidea — the squids and octopuses
- Phylum Arthropoda
  - Class Trilobita — trilobites
  - Class Ostracoda — ostracodes
  - Class Insecta — the insects

Phylum Echinodermata
- Class Blastoidea — blastoids
- Class Crinodea — sea lilies and feather stars
- Class Asteroidea — star fish
- Class Echinoidea — sea urchins, heart urchins, sand dollars

Phylum Protochordata (Hemichordata) — includes extinct graptolites

Phylum Chordata — chiefly vertebrate animals
- Class Pisces — fish
- Class Amphibia — frogs, toads, salamanders
- Class Reptilia — extinct dinosaurs, turtles, snakes, lizards
- Class Aves — birds
- Class Mammalia — mammals

The classification scheme elaborated above serves not only to group organisms according to relationships but to demonstrate, by the number of headings required, the diversity of the biosphere, as well. However, there are many more phyla and other major groupings that are important to biologists today, but are insignificant or unknown as fossils.

SELECTED FOSSIL-PRODUCING ANIMAL AND PLANT GROUPS

PHYLUM PORIFERA — THE SPONGES

The sponges are mostly marine multicellular animals in terms of basic organization but lack tissues or organ systems. The sponge body may be globular, cylindrical, disc-, or vaseshaped but is generally asymmetrical. Sponges characteristically have perforated walls (source of the phylum name which means pore-bearing) that are modified by folds and canals which greatly increase the food-gathering surface as water is pumped through the body. The body is supported by spicules composed of opaline silica, calcium carbonate (usually calcite), or an organic substance called spongin. Spicules are single or multi-rayed in various designs resembling tiny pitchforks, tripods, shepherd's crooks, tuning forks, barbells, and jacks. The spicules are more or less connected to form lattices. More commonly, however, only scattered spicules remain as the soft body decays.

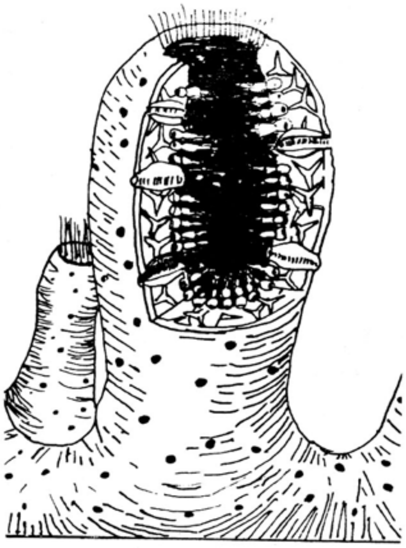
The archaeocyathans were cup- or cone-shaped individuals with perforated double walls and radial partitions, and were problematical sponge-like organisms without surviving relatives. On the other hand, another important fossil group, the stromatoporoids, which appear in many early reefs, secreted a more massive, layered skeleton and are now regarded as extinct sponges.

PHYLUM CNIDARIA

The aquatic, predominantly marine, cnidarians exhibit a degree of specialization greater than the sponges in having well-developed inner and outer tissues but lack organs seen in more advanced invertebrate animals. Two contrasting body forms, each rimmed by tentacles, characterize the phylum, one opening downward (medusa), the other upward (polyp). The tissues are organized around a radially divided digestive cavity, and the entire body of each individual cnidarian tends to be radially symmetrical. On the surface of the tentacles are special cells housing stinging capsules containing prey-paralyzing toxin. The exclusively marine and polypoid, bottom-dwelling members of the coral class, the Anthozoa, possess the most extensive fossil record owing to the secretion of a calcium carbonate exoskeleton built upwards from a basal platform that encases the body in a cylindrical or conical cup.

Division of the individual anthozoan exoskeleton, called the corallite, by radially disposed and vertical (septa) or horizontal (tabulae) plates serves to differentiate the orders of the class. Thus, the extinct Rugosa (individuals and colonies) and the colonial Tabulata with tiny cor- allites crossed by horizontal plates distinguish Paleozoic rocks from the Ordovician Period onward. The fossils of the Scleractinia, with septal divisions in multiples of six, are found only in Mesozoic and Cenozoic “rocks.

A solitary habit, as illustrated by the Paleozoic horn corals, is less common than the colonial structure associated with reef and other carbonate buildups dating from Paleozoic times. By means of asexual cloning, colonies of corals expand laterally and vertically. In today’s seas, species of both the sessile corals and the mobile soft-bodied scyphozoan jellyfish are common.



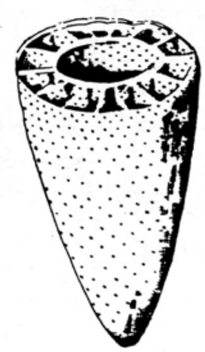
1. Modern Sponge × 15

2. Spicules of modern sponges × 30

3. Silurian sponge × 1

4. SIlurian sponge × ½

5. Devonian sponge × ½

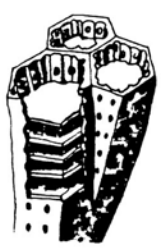


6. Cambrian archeocyathid × 1

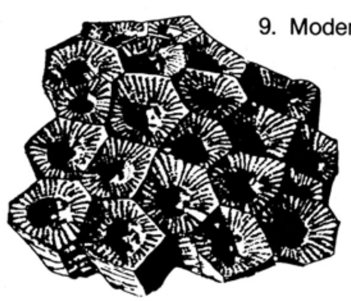
7. Silurian stromatoporoid × 2

8. Modern scleractinian coral × 6

9. Modern colonial scleractinian coral × ½



10. Silurian tabulate coral × 3



11. Mississippian colonial rugose coral × 1

12. Mississippian solitary rugose coral × 1

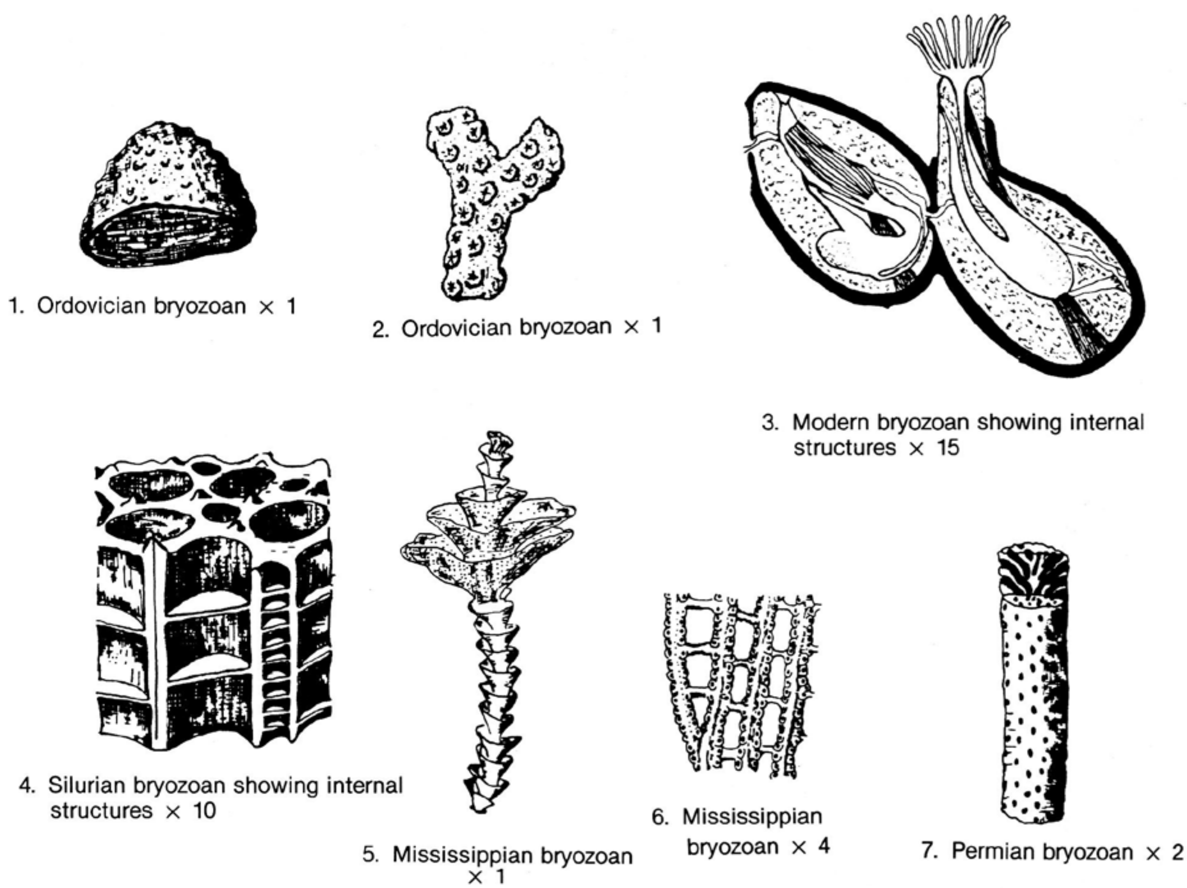
Porifera (1-7), Cnidaria (8-12)

PHYLUM BRYOZOA

The exclusively colonial fossils of bryozoans superficially resemble some colonial corals but the individual units are much smaller. Furthermore, unlike the radial coelenterates, the body plan of the individual bryozoan animal and the majority of the other members of the animal kingdom is fundamentally bilaterally symmetrical.

Typically, hundreds of tiny individuals, less than 1 mm long, are joined together in colonies with each animal secreting a calcite, chitinous, or membranous exoskeleton (zoecium) to form variously shaped colonial structures (zoaria) ranging from simple series of tubes that commonly encrust shells, to more complex zoaria. These zoaria may be upward-branching, rounded cylinders, or horizontally-encrusting, leaf-like expansions, or frond-like with vertical branches joined by cross bars so as to leave window-like openings (lacy), or flat-bottomed hemispherical masses. In some species, the lacy fronds are attached to a spiral base.

In addition to the tiny zoecial openings crowding the zoarium surface, low nodular mounds and flat areas may be regularily distributed over the colony surface. However, due to the minute size of the zoecia, high magnification is required to observe internal features. From the open end of each zoecial tube, a horse-shoe-shaped, tentacle-bearing, respiratory and feeding organ, the lophophore, is extruded and retracted by muscles. This device is comparable to one used by another filter-feeding organism, the brachiopod.

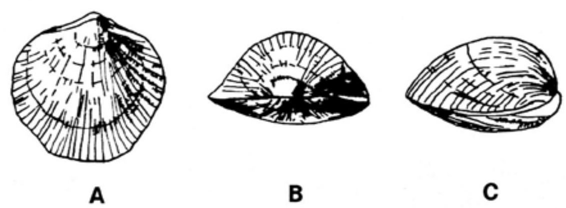


Bryozoans (1-7)

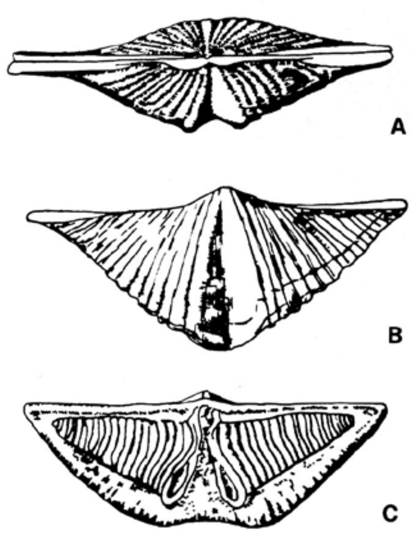
PHYLUM BRACHIOPODA

Brachiopods have a double-valved shell which is secreted in a variety of shapes and sizes at the edges of thin lobes of special ectodermal tissue called the mantle. The entire brachiopod shell is bilaterally symmetrical, but the plane of symmetry passes through the middle of each valve, rather than between the valves as is the case in many other animals with two-valved shells. As the shell grows periodically, concentric growth lines mark the successive stages of growth. In the largest division, the Class Articulata, the calcite valves are hinged near the posterior margin by projections (teeth) in the pedicle valve, which has an oval or triangular opening for passage of a fleshy stalk (pedicle). These hinge teeth fit into depressions (sockets) in the brachial valve. The lophophore is attached to the interior of the latter. In the case Inarticulata, the valves lack hingement and the typically small, thin, smooth shells are commonly composed of layered or mixed organic substances (chitin and protein) and calcium phosphate (apatite). Larger inarticulates resembling the living genus Lingula use one end of a continuously growing stalk-like pedicle to anchor the body to the bottom of burrows on the sea floor. The pedicle is used to attach the animal to the seafloor during all or part of the postlarval stage of life. Shell shape is related to the nature of the bottom on which the brachiopod resides and to the need to maintain the gape between the valves free of sediment.


8. Cambrian inarticulate brachiopod × 2

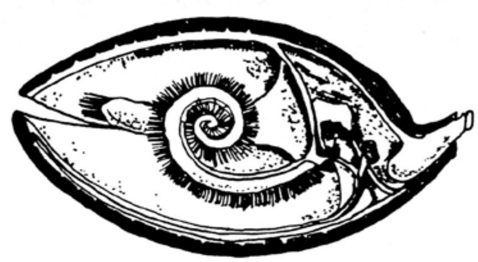


9. Silurian articulate brachiopod × 1



10. Mississippian articulate brachiopod. Shell is cut away in C to show spiral lophophore support × 1


11. Ordovician articulate brachiopod x 1


12. Modern brachiopod with shell cut away to show internal structures × 2

Brachiopoda (8-12)

PHYLUM MOLLUSCA

Part of the body wall, the mantle, secretes an external or internal shell, if present, composed of calcium carbonate (aragonite and/or calcite). The shell may consist of several unconnected parts, two parts, with or without articulation (clams), or one part, mostly in the form of a straight (some cephalopods) or coiled (most snails, other cephalods) cone with (cephalods) or without (snails) internal divisions {septa). The internal shell of some cephalopods may be reduced to a body support function (cuttlefish, squids).

An open space enclosed by the mantle, located forward in snails and to the rear in clams and other molluscs, houses paired gills, used primarily in respiration but serving also as a food-filtering screen in clams. The lower part of the body wall, the foot, is modified for locomotion (crawling, digging, swimming) or into tentacles used in predation. The formal names applied to some molluscan classes (e.g., Gastropoda = "stomach-foot") reflect. early recognition of this portion of the body but some confusion as to function. The three most important molluscan classes, in terms of quantitative representation in the fossil record, are discussed further below.

CLASS PELECYPODA (BIVALVIA)

Pelecypods (from the hatchet shape of the foot) are commonly called clams, and include mussels, scallops and oysters, the vast majority of which inhabit shallow marine waters. In some clams, alternating teeth and sockets in one valve, matching their opposites in the other, form a hinging mechanism. Other clams lack hinge teeth, and elastic ligaments and pads hold the valves in alignment and function to open the shell. One or two muscles close the shell in contrast to the two sets of opening and closing muscles in articulate brachiopods. On the smooth shell interior, elongate grooves, and circular depressions were once occupied by ligaments and the ends of adductor muscles. These features, along with a variety of tooth patterns, aid in identification, classification, and interpretation of life habit.

CLASS GASTROPODA

The predominantly marine snails evolved eventually to outnumber all other mollusks combined in both fossil and living species, a diversity that parallels the wide environmental adaptation within the class. With the development of a lung-like structure for breathing air, snails invaded land habitats first in the Pennsylvanian Period. Mostly crawling slowly over the shallow seafloor or soil surface on the muscular foot, snails carry a coiled shell on the back. Coiling in gastropod shells may be loose, with complete revolutions (whorls) just touching, or tightly coiled with an internal spiral structure at the coiling axis. The fossil record of snails includes many internal molds which limit our ability to identify many species.

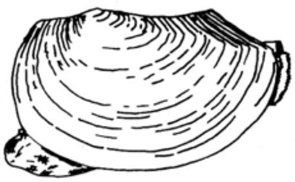
CLASS CEPHALOPODA

By Ordovician time, the nautiloids, the earliest members of this exclusively marine class had become the chief predators of the seas, equipped like the present-day cephalopods (squids, cuttlefish, octopus and pearly nautilus) with highly developed eyes, prehensile tentacles and rapid locomotion by means of jets of water. A fleshy tube, the siphuncle, passes through the

1. Tertiary clam × ½

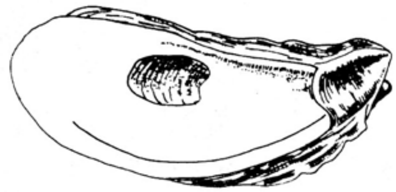
2. Tertiary clam × ½

3. Pennsylvanian clam × ½



4. Modern clam × 1

5. Cretaceous oyster × ½



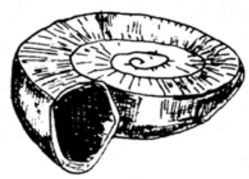
6. Modern oyster × ½

8. Modern gastropod × ½

7. Jurassic oyster × 1

9. Cretaceous gastropod × 1

10. Modern gastropod with shell cut to show inner spiral × 1



11. Ordovician gastropod × ½

12. Pennsylvanian gastropod × 1

13. Mississippian gastropod × 2

Mollusca, Pelecypoda (1-7), Gastropoda (8-13) interior chambers and the walls (septa) separating them. The unoccupied earlier chambers behind the living chamber were filled with gases and liquids or with mineral deposits as the nautiloid grew. In modern Nautilus, the gases in the chambers lend buoyancy to the animal within the water column.

The most useful feature for identification of fossil cephalopod shells is the pattern formed by the intersection of the edges of the septa with the inner shell wall. This intersection, called the suture, is straight or gently undulous in the straight, curved or coiled shells of nautiloids. Ammonoid shells have complexly fluted septaethat give similarly complex suture patterns. Three ammonoid suture types, goniatitic, ceratitic and ammonitic, successively evolved in the Devonian, Mississippian and Permian periods. Goniatitic ammonoids were most common in Paleozoic faunas, whereas the ceratitic and ammonitic forms were the dominant Mesozoic forms.

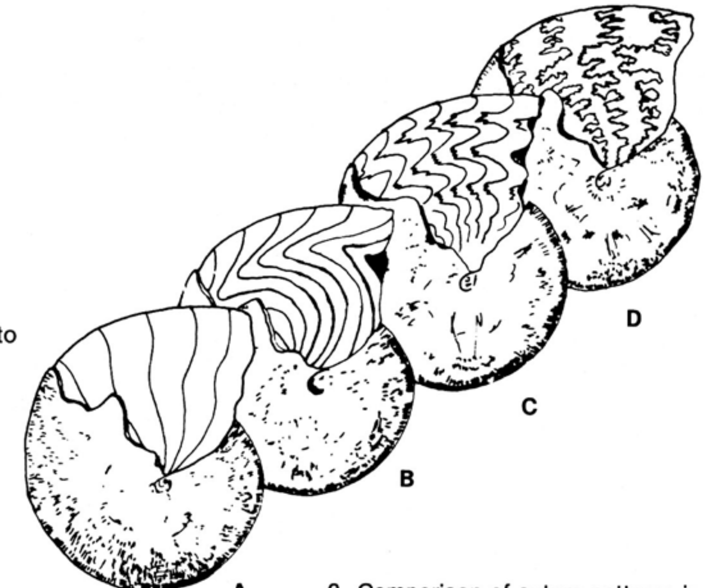
PHYLUM ARTHROPODA

More than three-quarters of all living species of animals are arthropods, the name derived from the segmented organization of the legs and feet. Insects, spiders, centipedes, lobsters, crabs, barnacles and several extinct groups, most notably the trilobites, belong to this phylum. Despite the visible abundance of members of the phylum and the long geologic histories of the main divisions, the fossil record is comparatively poor. Insect fossils, for example, are rare outside of exceptional volcanic ash deposits and resin droppings (amber) from trees. Only the ostracodes with a bivalved carapace of calcite and the trilobites with a calcite- impregnated chitinous exoskeleton are represented by an extensive fossil record.

Based on an invariable association with fossils of marine organisms, the trilobites appear to have been exclusively marine during their time range, the Paleozoic Era. Trilobites owe their name to the lobate curvature of three longitudinal divisions of the body, the axial lobe in the middle and the pleural lobes on the sides. From head to tail, there are also three main subdivisions, the cephalon, thorax and pygidium. In the segmented thorax region, the pleural lobes each bore ajointed appendage that was ysed for walking or swimming and supported a gill for breathing. Distinctive trace fossils resulted from the movement of these legs, both while the animal crawled and rested on the seafloor. A pair of antennae rose from the under surface of the cephalon, and paired compound eyes were located on the upper surface.

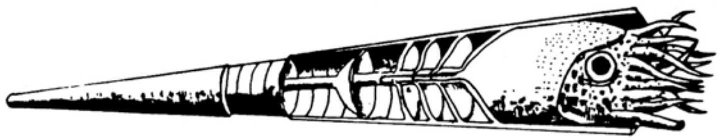
As is typical of many arthropods, complete or partial molting (shedding) of the external skeleton (exoskeleton) occurred before growth periods in both trilobites and the much smaller ostracodes. In trilobites, this resulted in breakage of the exoskeleton into several pieces, whereas the “bean-shaped” and bivalved carapace of the ostracodes usually became disarticulated into the two separate valves. As a result, the fossil record includes mostly molt stages of these animals.

1. Modern nautiloid with shell cut away to show internal features. × ⅓

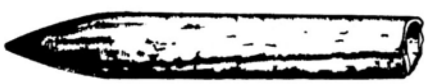


2. Comparison of suture patterns in (A) coiled anutiloid, (B) goniatitic ammonoid, (C) cerratitic ammonoid and (D) ammonitic ammonoid.

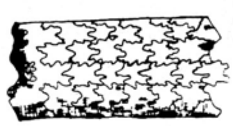
3. Ordovician straight-shelled nautiloid × 1



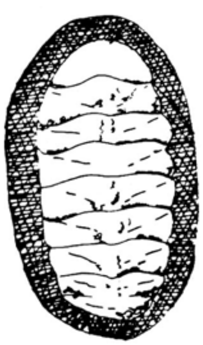
4. Reconstruction of Paleozoic straight-shelled nautiloid with shell cut away to show internal features. × ½



5. Jurassic coleoid (belemnite) × ½



6. Cretaceous straight-shelled ammonoid (fragment) × 1



7. Modern polyplacophoran × 1

8. Modern scaphopod × 2

9. Cretaceous coiled ammonoid × 1

. Mollusca: Cephalopoda (1-7), Polyplacophora (8), Scaphoda (9)

PHYLUM ECHINODERMATA

The knobby, often spine-studded surface of the multi-plated internal skeleton of the starfish and sea urchins is the basis for the “spiny-skin” name given to this exclusively marine phylum. Echinoderms also are recognized commonly by their generally five-fold (pentameral) symmetry. With the demise of the organism, the individual skeletal parts easily disarticulate. Even so, the characteristic calcite skeletal parts remain and can be identified.

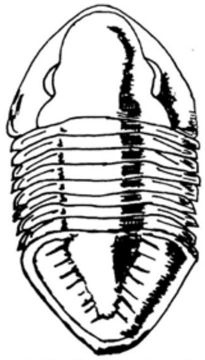
Echinoderms are commonly grouped into two informal subdivisions based on the degree of attachment to the seafloor. Pelmatozoa (echinoderms with a stem or stalk) are more or less permanently attached following a swimming larval stage. Eleutherozoa (free-moving echinoderms) generally are not attached to the sea bottom, but crawl over it, burrow into it or swim above it.

All classes of echinoderms were established by Ordovician time. However, it is the crinoids and allied pelmatozoans that dominated the Paleozoic, although by the end of it most of them had become extinct. In contrast, Mesozoic and Cenozoic echinoderm faunas have been dominated by echinoids and starfish.

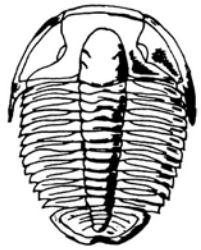
Blastoids resemble crinoids in having a theca of main body parts rising above a supporting stalk of many segments (columnals) attached at the base by a root-like system. The budshaped theca of the blastoid is composed of a uniform, symmetrical pattern of thirteen plates arranged in three rows. Embayments in each of the five principal plates house one of five ambulacraI areas equipped with rows of thread-like brachioles that were used for food capture.

Compared to the blastoid theca, the crinoid calyx is much more complicated in having a dorsal cup of two to many circlets of less regular plates and a ventral plated cover (tegmen) also. Five arms with ambulacral grooves originate at special cup plates (radials) and are used for food capture. The stalked support, rooted habit, and branched crown, gave rise to the popular but biologically inaccurate name “sea lily” applied to the crinoids.

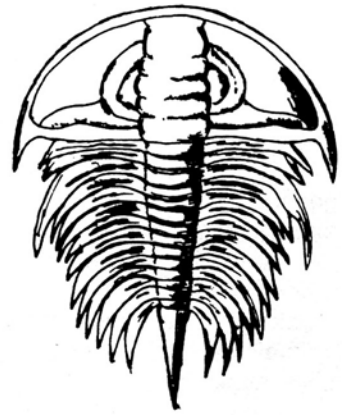
The echinoids, which compete in importance with the crinoids as contributors to the fossil record of echinoderms, include the sea urchins and sand dollars along with a number of extinct species first observed as fossils in rocks of Ordovician age. The skeleton (test) is a globular or flattened box composed of rows of plates of different shapes which are arranged into five ambulacral areas which alternate with the same number of interambulacral areas. The former distinguished by perforated plates which accomodate the tube feet of the water- vascular system. In life, the highly attractive plate design is hidden by numerous movable spines which are attached to knob-like bases on the skeleton surface. In reference to the degree of radial symmetry displayed by the skeletal architecture, echinoids are classified as either “regular” or “irregular” the latter group having a distinctly bilateral appearance. A jaw apparatus, composed of a number of sharp-edged plates and called Aristotle’s lantern occupies a large central opening in the skeleton surrounding the mouth. Echinoids are mostly muddy bottom sediment eaters and scavengers in contrast with the aggressively predaceous starfish. The “irregular” echinoids, which appear first in the Jurassic Period, include the sand dollars and heart urchins.



1. Ordovician trilobite × 1



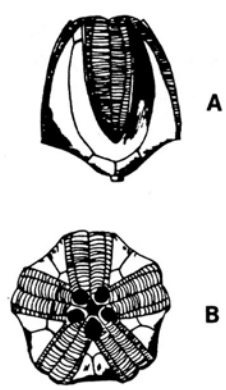
2. Cambrian trilobite × 2



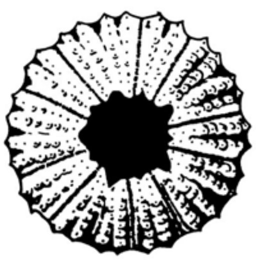
3. Cambrian trilobite × 1

4. Ordovician ostracode × 1 ½

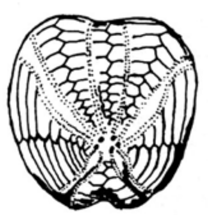
5. Silurian ostracode × 8



6. Mississippian blastoid × 1

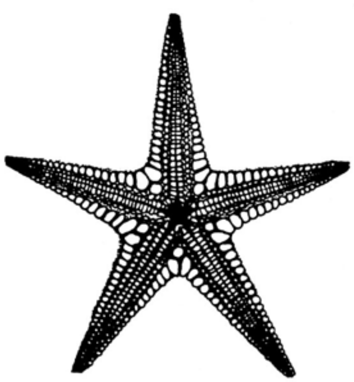


7. Cretaceous “regular” echinoid × ½



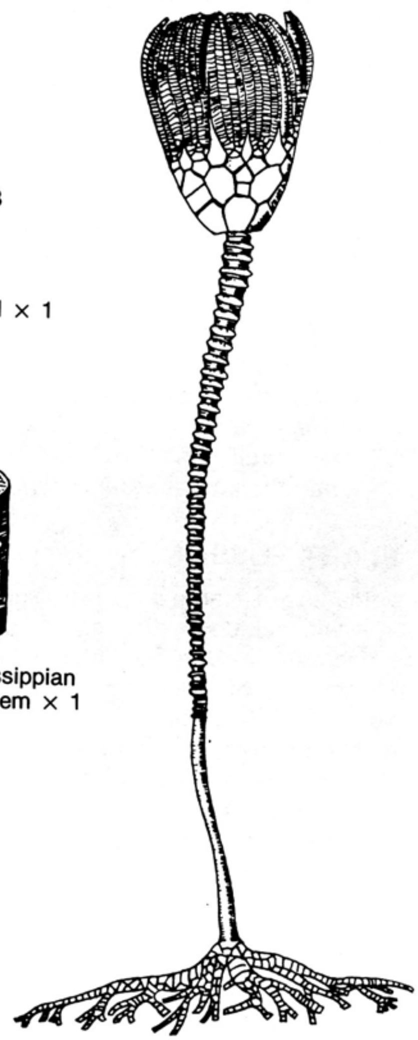
8. Cretaceous “irregular” echinoid × 1

9. Mississippian crinoid stem × 1



10. Modern starfish × ½

11. Triassic crinoid stem × 1



12. Reconstruction of complete Silurian crinoid × ½

Arthropoda (1-5), Echinodermata (6-12)

PHYLUM PROTOCHORDATA

There are a number of examples of fossil discoveries and collections made several years, even a century or more, before their assignment to a specific biological group has gained general acceptance by paleontologists and biologists. The majority have been fossils of long extinct organisms without modern relatives. Today, after two centuries of systematic shuffling back and forth, graptolites or, more formally, Graptozoa, are understood to be chitinoid colonial structures that housed numerous minute organisms belonging to an extinct group of hemichordates. Hemichordates are placed in the Phylum Protochordata which includes animals “intermediate” between the higher invertebrates such as echinoderms and the chordates.

When uncompressed graptolite specimens, rather than the more common compressed carbon films, are studied, the colonial skeleton (rhabdosome) is seen to be composed of linear series of tubular cups connected at the base to a continuous tubular portion in one group or thread-like rod in another. The style achieved on completion of colony growth provides a basis for recognizing evolutionary trends.

PHYLUM CHORDATA

In addition to a cartillaginous notochord, chordate animals possess, during one or more life stages, a dorsal nerve cord, a pharynx with gill slits, and typically, a tail. Of the nearly 45,000 living species most chordates are vertebrates in which a column of vertebrae (backbone) develops around and mostly replaces the notochord. In the bony fish, amphibians, reptiles, birds, and mammals, bone, composed of apatite replaces the initial skeletal cartilage completely, except between vertebrae and other parts. In some fish (lampreys, sharks, rays) there is no bone replacement.

As with fossils of other groups of organisms, the skeletal remains of vertebrates have provided a record of the order of first appearance beginning with the earliest fish in the Late Ordovician followed by the amphibians then the reptiles by the end of the Palezoic Era and, lastly, the mammals in the Triassic and birds in the Jurassic. More recently, sediments in the Late Cenozoic fault basins of East Africa have furnished a record of the ancestry of our own placental mammal species, Homo sapiens.

PLANT FOSSILS

Plants are a large and diverse grouping of photosynthetic organisms, which, for our discussion will include multicelled and single-celled forms, and also will include the photosynthetic monerans. The dominant type of preservation of plant fossils is by carbonization, because the “skeletons” of most plants are formed by complex organic substances including cellulose and lignin. Some marine plants, however, are capable of secreting mineral material. These plants mostly belong in the broad grouping of algae, the most conspicuous mineral remains of which are calcite and aragonite. In addition to the preservation of either organic or mineral body parts, some algae, previously mentioned, are capable of forming layered sedimentary accumulations (stromatolites) by trapping fine sediment particles on their sticky cell and filament surfaces.

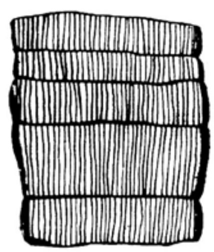
Fossils of land plants exhibit an enormous variety of shapes and forms. Some of the most common types of land plant fossils are pollen and spore grains, but the most obvious are impressions and carbon films of leaves plus petrified wood. Other parts, such as flowers and seeds are much less common.

1. Ordovician graptolite × 2

2. Ordovician graptolite × 1½

3. Ordovician graptolite × 1

4. Ordovician graptolite × 1

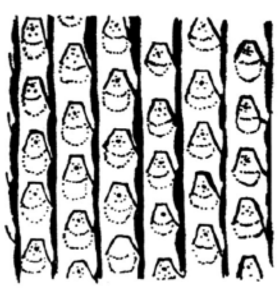


5. Pennsylvanian cast of branch pith cavity × ½

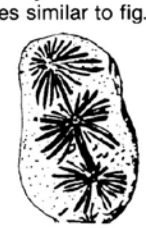
6. Reconstruction of Pennsylvanian tree composed of branches similar to fig. 5 and 10.

7. Pennsylvanian fern leaf × 1

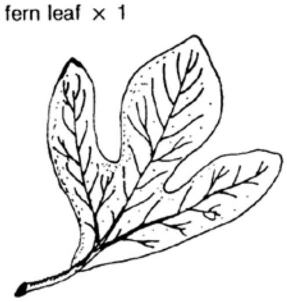
8. Pennsylvanian fern branch ×



9. Pennsylvanian tree bark × ½



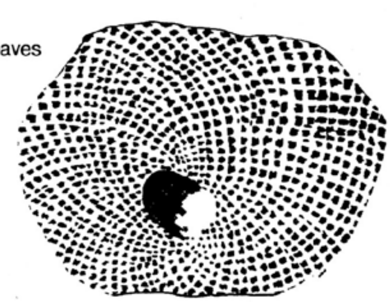
10. Pennsylvanian leaves and stem × 1



11. Tertiary angiosperm leaf × ½

12. Pennsylvanian tree bark × ½

13. Tertiary gymnosperm branch × ½



14. Ordovician calcareous green alga × 2

Hemichordata (graptolites) (1-4), Plants (5-14)

FOSSIL IDENTIFICATION

name _______________

Sample # 1. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 2. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 3. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 4. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches

Sample # 5. Kingdom_____________ Phylum______________ Class________________	Notes	Sketches
Sample # 6. Kingdom_____________ Phylum______________ Class________________	Notes	Sketches
Sample # 7. Kingdom_____________ Phylum______________ Class________________	Notes	Sketches
Sample # 8. Kingdom_____________ Phylum______________ Class________________	Notes	Sketches
Sample # 9. Kingdom_____________ Phylum______________ Class________________	Notes	Sketches

Sample # 10. Kingdom_____________ Phylum______________ Class_______________	Notes	Sketches
Sample # 11. Kingdom_____________ Phylum______________ Class_______________	Notes	Sketches
Sample # 12. Kingdom_____________ Phylum______________ Class_______________	Notes	Sketches
Sample # 13. Kingdom_____________ Phylum______________ Class_______________	Notes	Sketches
Sample # 14. Kingdom_____________ Phylum______________ Class_______________	Notes	Sketches

Sample # 15. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 16. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 17. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 18. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches
Sample # 19. Kingdom______________ Phylum_______________ Class________________	Notes	Sketches