10

Fossils and Their Living Relatives: Protists, Sponges, Corals, Bryozoans, and Brachiopods

WHAT YOU WILL NEED

1. Study set of fossil sponges, corals, bryozoans, and brachiopods. (Available from Wards Natural Sci. Establ.)
2. Several genera of foraminiferida mounted on an opaque slide.
3. Strew slides of radiolarians and of diatoms. (Slides available from Ward's Natural Sci. Establ.)
4. Microscope and lamp.

Note to Instructors

Because it is difficult to adequately describe representatives of each of the eight major phyla of frequently fossilized invertebrates in a single laboratory period, we have arbitrarily divided the fossil exercises into two chapters. In this chapter, we consider the unicellular invertebrates, as well as the Porifera, Cnidaria, Bryozoa, and Brachiopoda. In Chapter 11, mollusks, arthropods, echinoderms, and plant fossils are considered. The use of fossils (including trace fossils) in stratigraphic and paleoenvironmental studies is examined in Chapter 12.

INTRODUCTION

WHAT IS A FOSSIL?

If we inquire into the Latin origin of the word **"fossil,"** we find that the term refers to anything dug out of the earth. Modern usage, however, restricts the meaning to remains or traces of life of the geologic past. It is difficult to assign absolute limits in years to the expression "geologic past." Most paleontologists agree that in order for the remains of an organism to be regarded as a fossil, the organism must have lived prior to the beginning of recorded human history. Remains of life from Pleistocene (Ice Age) or older rocks are definitely fossil. In addition to its rather intangible quality of age, a fossil must also provide some evidence of at least part of the anatomy of the organism that produced it. Even tracks, trails, borings, burrows, and preserved excrement are considered fossils *(trace fossils)* because they provide clues to an animal's size, shape, and mode of life.

Although there are rare examples of fossils in lava flows or occurring as distorted forms in metamorphic rocks, most invertebrae fossils are found in shallow marine sedimentary rocks. Life flourishes on the floors of shallow seas, and burial by falling sediment is a relatively continuous and often rapid process. At certain localities, however, abundant fossils of nonmarine animals and plants can be found. For example, remains of dinosaurs are often found in fluvial (river), lacustrine (lake), deltaic, or eolian sedimentary rocks.

PRESERVATION OF FOSSILS

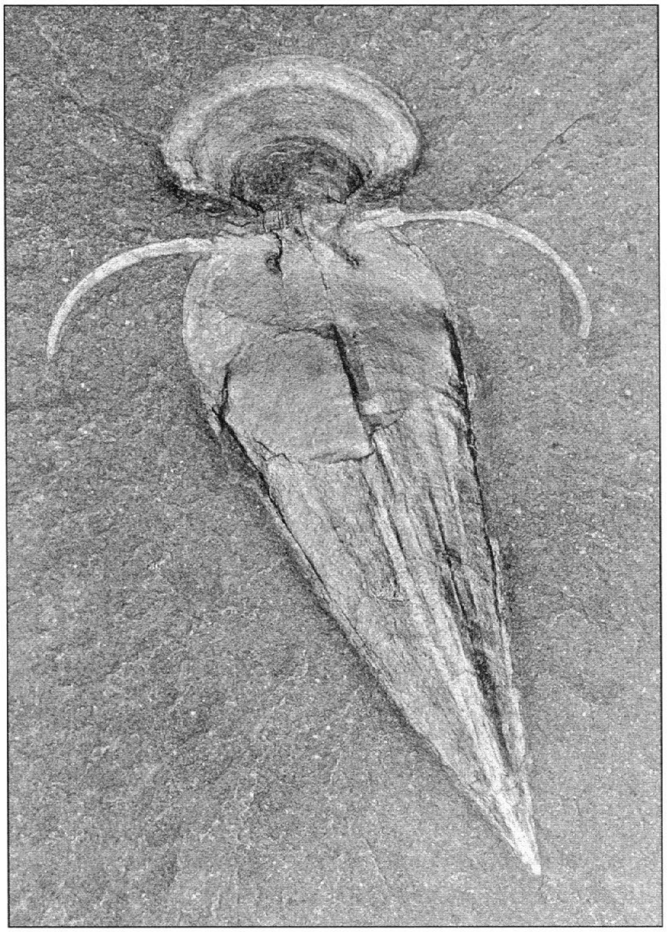
When one considers the many factors that tend to destroy an organism after its death, it seems remarkable that fossils are as common as they are. Chemical decomposition, erosion, attack by scavengers, and a multitude of geologic processes make the odds against fossilization formidable. The possession of hard skeletal parts and rapid burial in sediment increase the chances that the animal or plant will leave a fossilized relic of itself.

To many, the term fossil implies **petrifaction**—literally, a transformation into stone. This may occur by gradual addition of a chemically precipitated substance into pore spaces **(permineralization),** or by a molecular exchange of substances that were once part of the organism with other substances carried in by percolating water solutions **(replacement).** Fossils replaced or permineralized by calcium carbonate, silica, or iron sulfide are common. A process of fossilization known as **carbonization** results when soft tissues are preserved as films of carbon. Soft-bodied organisms such as jellyfish, worms, and graptolites, as well as leaves of trees, may be preserved in this way. However, not all blacks and shiny fossil films are the result of carbonization. For example, many of the soft-bodied animals of the Burgess Shale fauna from a famous locality in British Columbia are preserved as black, reflective films composed of calcium and magnesium aluminosilicates (Fig. 10.1). The remarkably diverse and exquisitely preserved Burgess Shale organisms are evidence of the veritable explosion of life during the Cambrian Period.

Another form of preservation, common for the shell-bearing invertebrates, develops when the shell material is progressively removed by leaching, so as to leave a void in the rock bearing the surficial features of the original shell. Such fossils are called external **molds.** If the cavity on the

Figure 10.1 *Hyolithus carinatus.* The photograph illustrates the nature of preservation in fossils of the Middle Cambrian Burgess Shale. *Hyolithus carinatus* is a hyolith. The shell is subtriangular in cross section and had a small operculum that served to close the opening of the shell. Two curved appendages probably helped to support the animal on the ocean floor.

Courtesy of Chip Clark, Museum of Natural History, Smithsonian Institution.



inside of the shell is filled with sediment and that filling preserved, it becomes an *internal mold.* A **cast** is formed when the void between the internal and external mold is filled with mineral matter. Thus the cast becomes a replica or model of the original shell (Fig. 10.2).

Replacements, permineralizations, carbonizations, molds, casts, tracks, trails, and imprints are all examples of preservation. In geologically young rocks, bone or shell material may be preserved without any significant alteration. Unaltered soft tissue requires extraordinary conditions for preservation. Insects trapped in amber and mammals found frozen in Arctic soils are dramatic, but very rare, examples of such preservation.

In addition to their interest in the discovery and identification of fossils, paleontologists examine fossils and the rock enclosing them in order to determine what occurred to the original organisms from the time they died to the time they reached their fossilized state. The term *taphonomy* refers to the study of events affecting an organism from death to fossilization. Taphonomic study may reveal if a lineage of organisms became extinct as a result of environmental changes, or whether the absence of fossils attributed to extinction was merely caused by dissolution, or other modes of destruction of fossils, after their burial. It may inform us if the organisms actually lived at the site where they were discovered or were carried to that place from a distant, and possibly very different, habitat.

Classification and Nomenclature

Because of the large numbers of organisms that have lived or are now alive, random naming would result in much confusion. Realizing this, the Swedish naturalist Carolus Linnaeus (1707–1778) established a system of naming animals

Figure 10.2 Diagram to explain molds and casts. (A) Cross section through the valves of a clam that has been buried and filled in with sediment. In (B), the original shell matter is dissolved, leaving a cavity or mold in the sediment or rock. In (C), mineral matter has been precipitated within the mold to form a cast that resembles the original shell. (D) The impression of the exterior of one valve of the clam in the enclosing sediment forms an external mold. (E) The lithified sediment that once filled the original shell or the cast constitutes an internal mold.

From Levin H. L., *Ancient Invertebrates and Their Living Relatives,* Upper Saddle River, NJ: Prentice Hall, 1999.

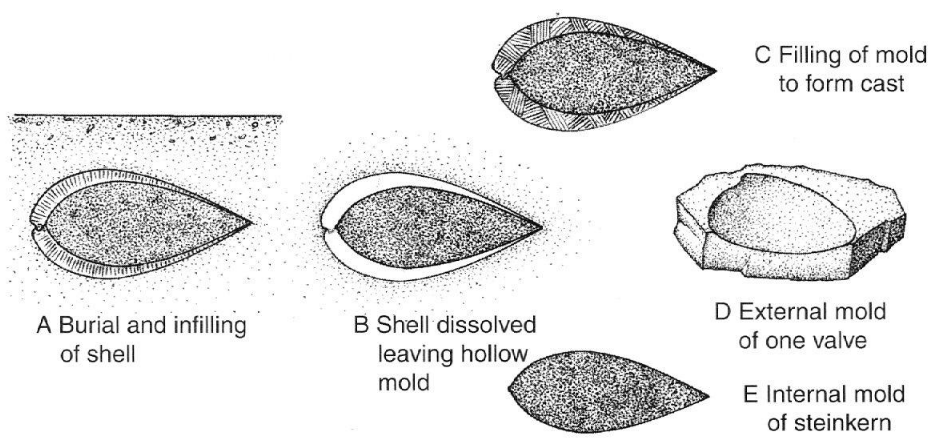


Table 10.1 Hierarchy of Taxonomic Groups

Kingdom	Animalia	Animalia
Phylum	Arthropoda	Chordata
Class	Crustacea	Mammalia
Order	Decapoda	Carnivora
Family	Nephrosidae	Canidae
Genus	*Homarus*	*Canis*
Species	*Homarus americanus*	*Canis familiaris*
Individual	a common lobster	a pet dog

and plants in 1758. The Linnaean scheme recognized structure as the basis for classification and established a system that includes binomial nomenclature at the species level. The name of a species consists of two parts, the generic name and the trivial name. For example, the scientific name for a dog is *Canis familiaris.* Both names are italicized or underlined, and the generic name is capitalized.

The basic category in taxonomy is the **species.** Species may be defined as groups whose members will interbreed and (except for sex differences) are more like one another than like any member of another similar group. The individuals, which are ultimate items of classification, can thus be grouped into species, the species combined into genera (singular, *genus*), the genera into families, and so on to successively larger divisions (Table 10.1). In this scheme, the smaller the category is, the more similar are its members.

The use of genus and species provides an efficient and precise nomenclature. The student may ask his professor to see a specimen of *Mytilus edulis,* and both the student and professor know that a certain species of common clam must be produced. It is difficult to guess the professor's reaction if the student asked to see a "whaddayacallit made of two lopsided, partly joined discs."

The definition of species must be modified when one is studying the fossil remains of extinct organisms. Obviously, the paleontologist cannot directly determine the ability or inability to interbreed. He therefore considers a species as a group of organisms whose individual differences both are small in comparison with their differences from other groups and are of the kind and magnitude to be expected in interbreeding populations.

When Linnaeus formulated his binomial system of nomenclature, he assumed that all life could be divided into two large categories, namely, the *Kingdom Animalia* and the *Kingdom Plantae.* In Linnaeus's time, the distinction between plants and animals seemed readily apparent. Shortly thereafter, however, unicellular creatures were studied that were simultaneously photosynthetic, like plants, and capable of ingesting food and moving about like animals. For such unicellular organisms having intergrading combinations of plant and animal characters, the biologist Ernst Haeckel proposed a third kingdom, the *Kingdom Protista,* in 1886. (The term Protoctista has recently been offered as a replacement for Protista.) Protists include a vast array of yellow-green and golden-brown algae and single-celled creatures once simply called "protozoans." Eventually, even the three-kingdom classification proved to be inadequate.

Figure 10.3 Modern stromatolites formed within the intertidal zone at Shark Bay, Australia.
Courtesy of J. W. Schopf.

The *Kingdom Monera* was established for asexually reproducing, unicellular microorganisms so primitive that they lack a cell nucleus and special cell organelles ("little organs" located within the larger cell that carry out certain cellular functions). Various bacteria, as well as the cyanobacteria (formerly called blue-green algae), are members of the Kingdom Monera. For geologists, the most familiar fossil formed by the activities of monerans like cyanobacteria are the stromatolites. *Stromatolites* are thinly laminated accumulations of calcium carbonate having rounded, cabbagelike, branching, or columnar shapes. Living cyanobacteria can be observed to form similar structures today (Fig. 10.3). Fine particles of calcium carbonate settle between the minute filaments and strands of the sticky algal layer and are bound within the gelatinous sheath. Successive additional layers result in fine laminations. The remains of filaments and spheres of cyanobacteria with fossil stromatolites (Fig. 10.4) indicate that ancient stromatolites formed in the same way. The cyanobacteria are photosynthetic organisms

Figure 10.4 2.3 billion-year-old fossil stromatolites from southern Africa.
Courtesy of J. W. Schopf.

and thus liberate oxygen. The presence of stromatolites over 3 billion years ago indicates that these organisms played a significant role in the production of atmospheric oxygen in the earth's early atmosphere.

Stromatolites range in age from the Archean to the present. Modern forms prefer the intertidal zone where their tops are at the high-water mark. Today's stromatolites are relatively short (rarely more than a meter tall), whereas some Proterozoic stromatolites exceeded 6 m in height.

The final kingdom of the five-kingdom classification consists of the Fungi. Fungi require such special placement because they depend on a supply of organic molecules for nutrition, as do animals, yet they absorb nutrients as do plants. Fossils of Fungi are rare, but fungal spores are known to occur in ancient Precambrian cherts.

The five-kingdom classification is based on the observable traits of organisms. These traits are important indicators of evolutionary relationships. Another indicator of relationships is the structure of large molecules in the cell such as ribonucleic acid (RNA). Comparison of these molecules in different kinds of organisms indicates that such superficially dissimilar groups as plants, animals, and fungi are actually related, and that the kingdom Monera of the five-kingdom system actually contains two distinct kinds of microorganisms. To account for the evolutionary relationships revealed by molecular biology, it has been proposed that all life be divided into three great groups termed *domains.* They are named *Bacteria, Archaea,* and *Eukaryia.* The domain Bacteria includes the cyanobacteria, purple sulfur bacteria, and several non-photosynthetic groups of microbes. Heat-tolerant microbes called thermophiles and methane-producing bacteria are placed in the Archaea. Both the *Bacteria* and *Archaea* consist of organisms that would be placed in the Monera of the older, traditional classification. All other forms of life have cells with a discrete nucleus. They constitute the domain Eukarya.

Study Questions

1. In life, nearly all snails (Class Gastropoda) build their shells out of calcium carbonate. What type of fossilization has probably occurred in a fossil snail that is composed of silica?

2. A stratum exposed at the base of a vertical cliff contains the fossil shells of clams resting in their "living position" within the rock. Several meters above this stratum, another bed contains the same species of clams, but the shells are abraided, broken, and jumbled within the rock. What taphonomic inference can be made from these observations?

3. Why is the older biological classification of all organisms into either the Kingdom Plantae or the Kingdom Animalia no longer followed?

4. Considering that sandstone is more permeable than shale, would one be more likely to find the *unaltered* remains of a clam in sandstone or shale? Why?

5. Why are there more fossils of organisms that lived in the ocean than there are of organisms that lived on the continents?

6. What is the basis for the inference that Precambrian stromatolites lived in relatively shallow, well-lighted parts of the sea?

7. What is the relation between the spread of Precambrian stromatolites and the evolution of the earth's atmosphere?

8. Describe a hypothetical scenario in which the body of a dinosaur would eventually become a fossil in floodplain deposits of the Cretaceous Period.

Fossil and Living Protists

Protists include a variety of microorganisms, some clearly "animal" in their characteristics and some that combine some of the traits of both plants and animals. Because they have hard parts that are preserved as fossils, coccolithophorids, diatoms, foraminiferida, and radiolaria are protists used by geologists in stratigraphic studies. In addition to their abundance in the fossil record, these protists are so small that they can be recovered intact even in broken chips of rock brought to the surface in the course of drilling for oil. The geologic ranges of some frequently fossilized protists are depicted in Figure 10.5.

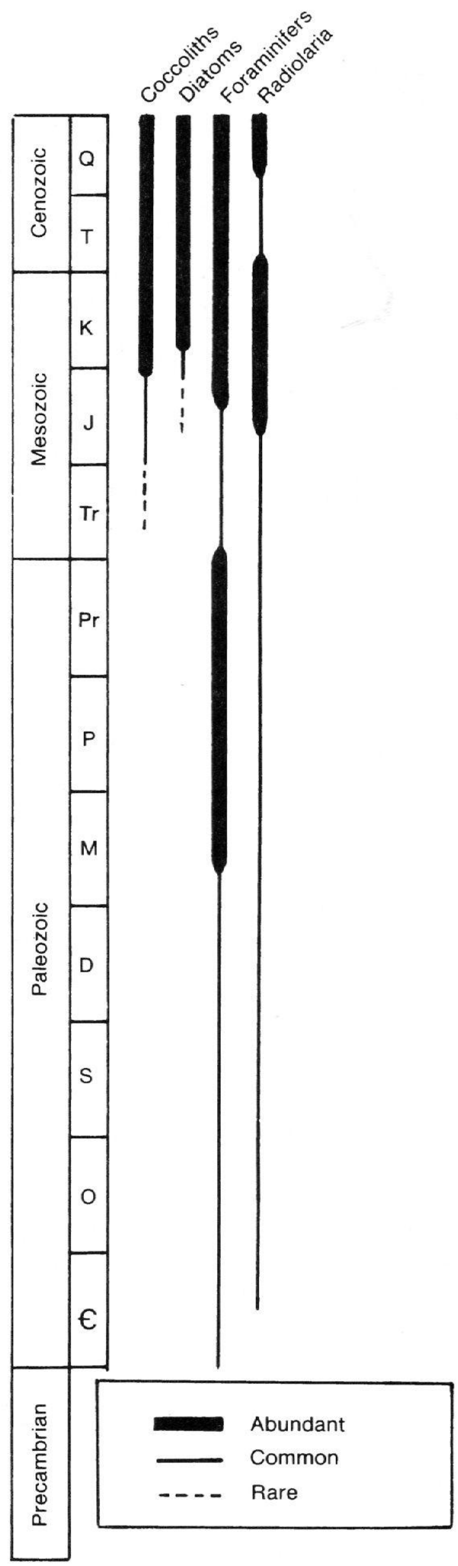
Coccolithophores

Coccolithophores are unicellular, planktonic, golden-brown **algae.** The usually spherical cell of the coccolithophore is called a **coccosphere** (Figure 10.6), and is covered by intricate calcium carbonate skeletal structures called **coccoliths** and **discoasters** (Fig. 10.7). Although usually less than 30 micrometers in diameter (1 micrometer equals 0.001 mm), these tiny structures are marvels of geometrically precise construction.

Most coccoliths take the form of two elliptical discs, stacked one above the other and joined at the center by a hollow stud. The discs are concave on one side, so that they are able to fit closely around the outside of the spherical coccolithophorid cell. Each disc of the coccolith is itself composed of still smaller elements uniformly arranged in overlapping circular or spiral patterns. With astonishing precision, the living cell exerts an exact control on the size, shape, and arrangement of the smaller elements that compose the coccolith.

Discoasters are simpler in construction than coccoliths. They are recognized by their radiate or stellate symmetry. The common genus *Discoaster,* for example, is a star-shaped

Figure 10.5 Geologic ranges of some frequently fossilized Protists.



disc composed of variously shaped radiating arms. *Braarudosphaera* has five plates arranged in pentaradial fashion. Each five-plate unit fits together with its neighbors to form a structure rather like a geodesic dome.

Coccolithophores began to occur abundantly during the Jurassic. Thereafter, they were particularly numerous and diverse during the Cretaceous, Eocene, Miocene, and Recent (Fig. 10.5).

Study Questions

1. Most coccoliths are recovered from soft, calcareous sediments like chalk. Why are they rarely obtained from well-indurated rocks or recrystallized rocks?

2. Label two discoasters and two coccoliths directly on Figure 10.7.

3. In samples of the ocean floor, coccoliths are most abundant in pelagic calcareous oozes. They are rarely encountered at great depth or in the coldest parts of the ocean. How do you account for this distribution?

4. What would be the maximum diameter (in micrometers) of a coccolith whose greatest diameter was 0.0025 mm?

Figure 10.6 A complete coccosphere of the coccolithophorid **Cyclococcolithus.** Diameter about 30 micrometers.

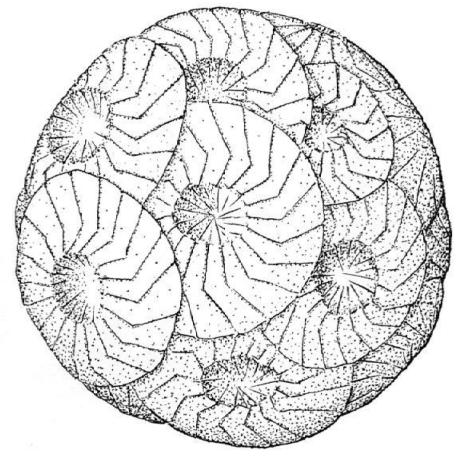
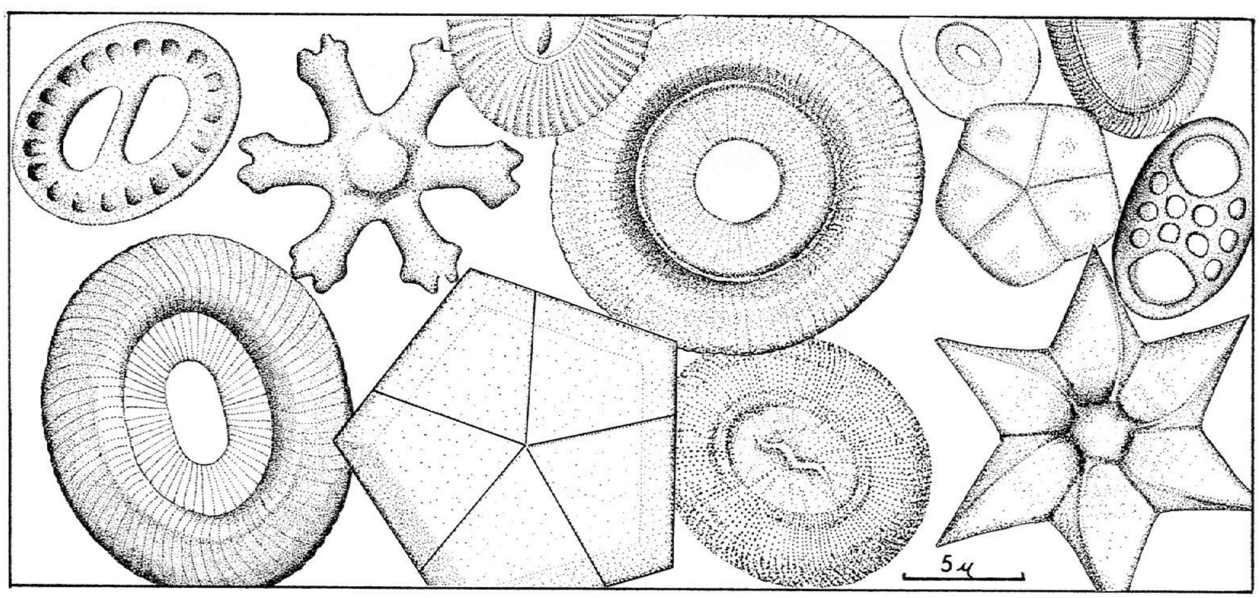


Figure 10.7 Coccoliths and discoasters of Tertiary age.



5. What would be the maximum (oldest) geologic age for a sedimentary rock containing coccoliths (see Fig. 10.5)?

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Diatoms

Diatoms (Fig. 10.8) are microscopic, one-celled aquatic algae, having beautifully constructed siliceous cell walls that are in two parts and fit together like the halves of a tiny pill box (Fig. 10.9). Myriads of diatoms live in the surface waters of oceans and lakes. The delicate siliceous coverings (frustules) of dead diatoms rain down continuously onto the floors of the seas, and they may accumulate to form a lightweight porous rock called diatomite.

Study Questions

1. Diatomite is quarried for use as an abrasive (e.g., in toothpaste) and as a chemical filter. On what property does its use as an abrasive depend? Why might the remains of diatoms make good chemical filters?

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Figure 10.8 Living and fossil diatoms (magnified about 300×).

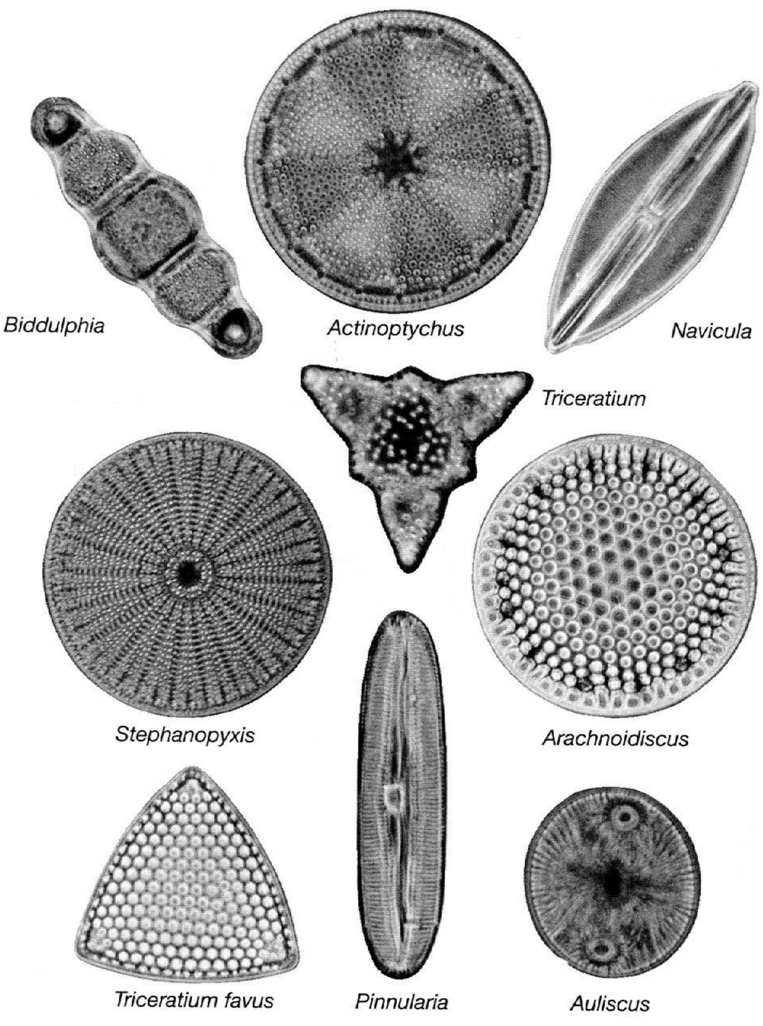
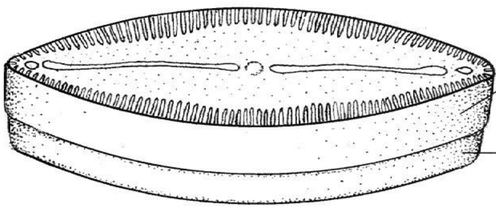


Figure 10.9 A freshwater diatom. The siliceous covering of the cell consists of two overlapping parts called valves. The inner or lower part is the hypotheca, and the upper part is the epitheca (magnified 500 times).



2. Examine the slide of diatoms with the aid of the microscope and substage lamp. Prepare a simple sketch of three different forms in the space below.

Sketch diatoms here

Receptaculitids

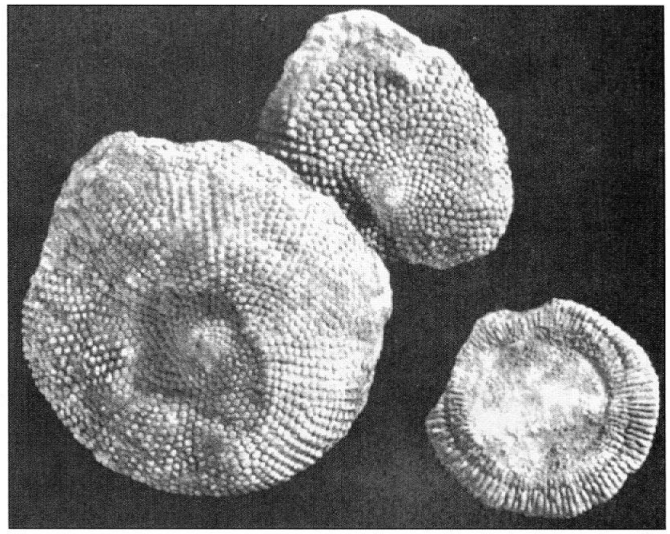
Receptaculitids are stratigraphically useful early Paleozoic fossils that remind one of the seed-bearing central area of a sunflower. As a result, amateur collectors have dubbed them the "sunflower corals." They are neither flowers nor corals, however. Most paleontologists believe they are lime-secreting green algae. The receptaculitid named *Fisherites* (Fig. 10.10) is a guide fossil used in correlating Ordovician to Devonian strata.

Foraminiferida

The members of the Order **Foraminiferida** (Fig. 10.11) are nearly all marine organisms that build their shells, called **tests,** by adding chambers in one or more rows, in coils, or in spirals. Foraminiferida means pore bearing, and refers to the large number of small holes *(foramina)* that perforate the tests of some species, through which stream thin pseudopodia of protoplasm. A larger opening, the **aperture,** is also usually present. Although the majority of tests are composed of calcium carbonate, some construct their shells of sediment

Figure 10.10 *Fisherites* (formerly known as *Receptaculites*).

Courtesy of Ward's Natural Science Establishment, Rochester, New York.



particles, some form them of a chitinous substance, and others secrete siliceous shell material. The chambers are separated from one another by **septa,** which are indicated on the exterior of the shell by **sutures.**

Most species of foraminiferida are bottom dwellers *(benthic)*. Fewer species, but large populations, are free floating *(planktonic)*. The empty shells of these planktonic foraminiferida (Fig. 10.12), along with cocoliths accumulate in large numbers in the deep-sea sediment known as calcareous ooze. In the past, many calcareous oozes have been lithified to form a variety of limestone known as chalk.

The rarity of foraminiferida remains in rocks older than Silurian may imply a lack of hard skeletal parts in older forms. Early foraminiferida constructed spherical, tubular, or chambered shells composed of cemented particles of fine sediment. By Late Paleozoic time, a group known as fusulinids became abundant and widespread. The fusulinids developed marvelously complex internal shell structures (Fig. 10.12) but take their name from their fusiform shape, which resembles a grain of wheat (see *Fusulina* and *Schwagerina* on Fig. 10.11). A milestone in foraminiferal history came in the Cretaceous, when planktonic forms (Fig. 10.13) made their appearance and expanded rapidly. Since the Cretaceous, the entire order has flourished and provided many useful guide fossils for stratigraphic correlation.

Study Questions

1. Foraminiferida index or guide species *Uvigerinella sparsicostata, Uvigerina gallowayi,* and *Nonion affinis* are found to be characteristic of a stratum penetrated in an oil well located at A in Figure 10.14. The index species were recovered at a depth of 1950 m. The same well encountered an oil-producing sandstone stratum 30 m thick at a depth of 2650 m. A second well is begun

Figure 10.11 Foraminiferida.

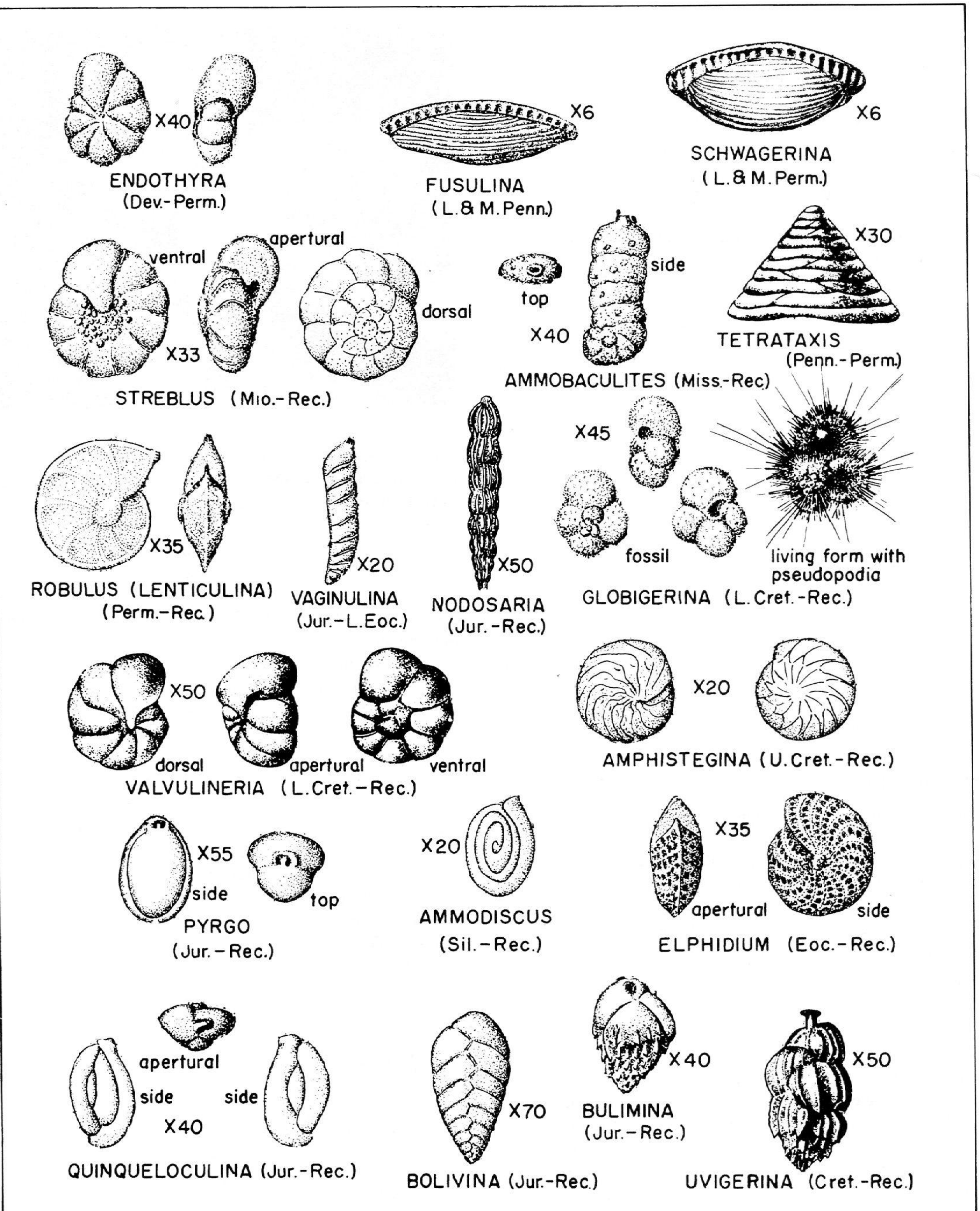
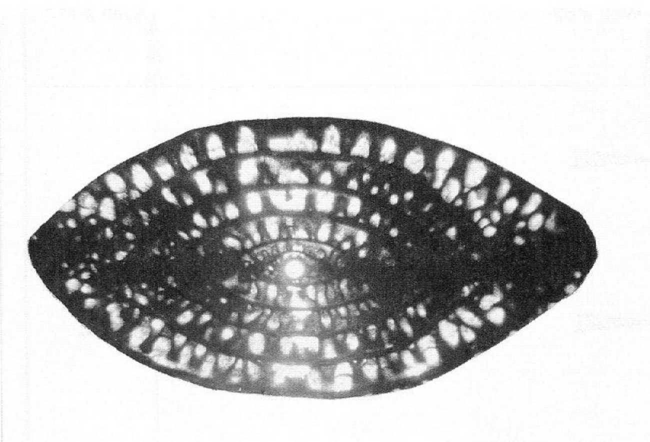


Figure 10.12 Thin section of a fusulinid showing complex internal structure. Length of specimen is 6 mm.

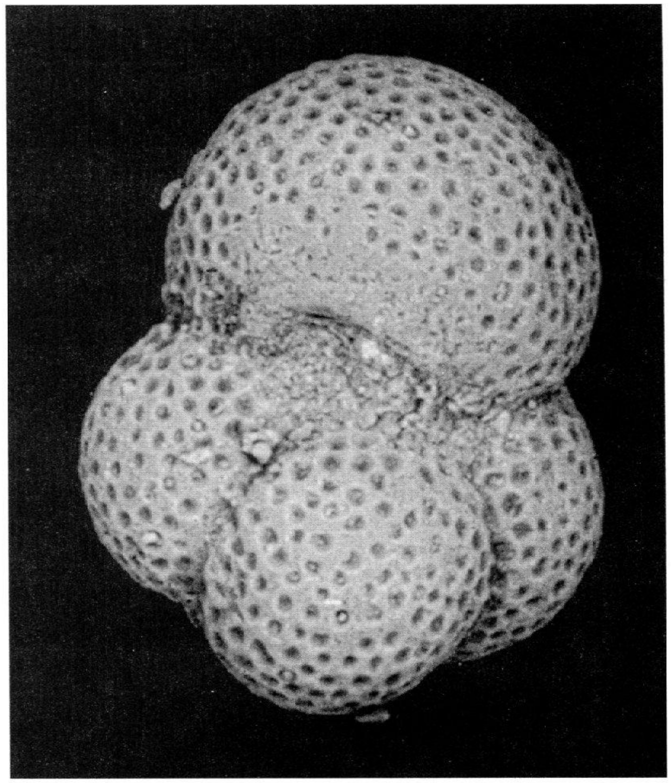


at location B, 2 km from the first. In the second well, the index species are encountered at a depth of 1350 m.

a. At what depth will the oil zone be reached at the second location? State the assumptions you used to reach your conclusion.

b. Assume that the shale and sandstone have not changed in thickness, and complete the rock column for well B.

Figure 10.13 The planktonic foraminiferida *Globigerinoides.*



2. In Figure 10.15 a distinctive foraminiferida assemblage is encountered at a depth of 410 m in well #34. In well #62, an identical assemblage is encountered at 400 m and again at 1200 m. In well #71, the assemblage occurs at 1200 m.

a. On the diagram, draw in a fault to indicate how faulting may have caused the repeated assemblage in well #62.

Figure 10.14 Use of foraminiferida in predicting drilling depth.

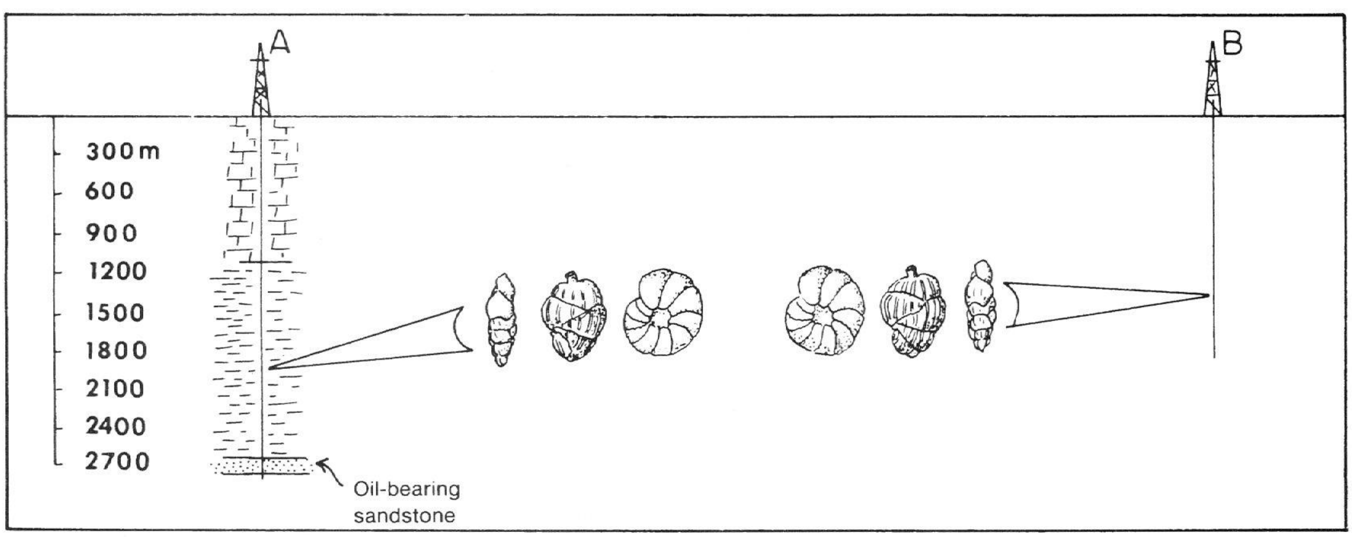
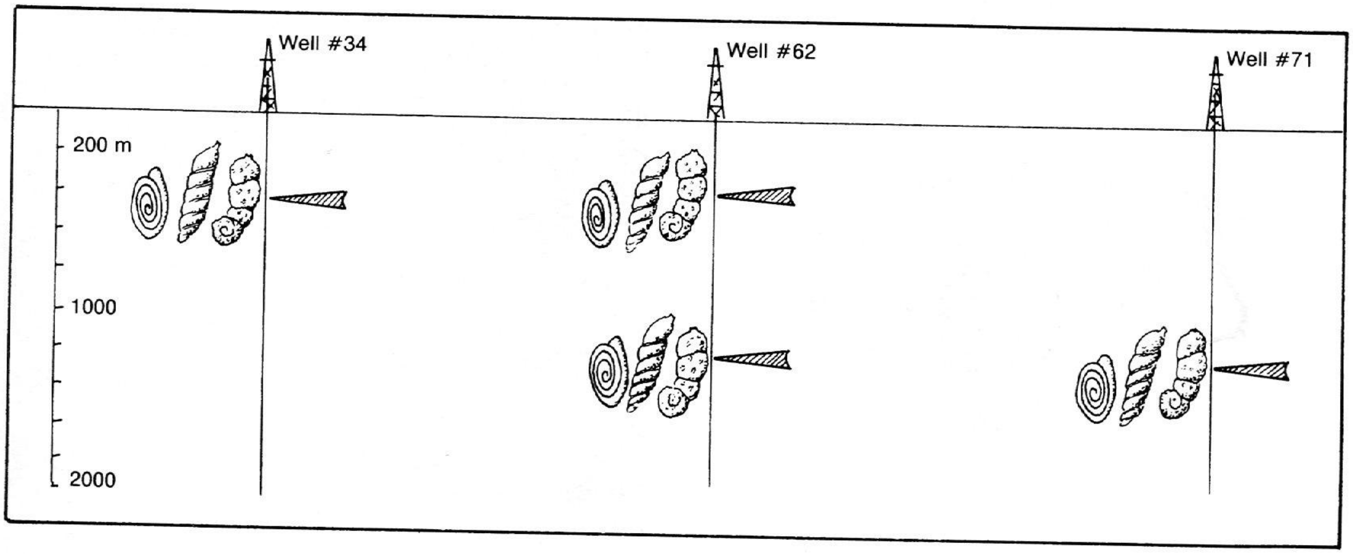


Figure 10.15 Recognizing subsurface structures with index fossils.



b. What is the name given to this type of fault? (See Chapter 14 for a summary of fault terminology.)

3. Would **benthonic** or **planktonic** foraminiferida be the most useful for indicating the depth of water in which a stratum was deposited? Why might an oil geologist be interested in this type of information?

4. Why are planktonic foraminiferida generally considered more useful in intercontinental stratigraphic correlation than benthonic foraminiferida?

5. In some areas of the present sea floor, foraminiferida tests are accumulating at the rate of 1 cm per 1000 years. At this rate, how thick a deposit would have accumulated during the 65-million-year duration of the Cenozoic era, if no allowance is made for compaction?

6. Examine the prepared slide of fossil foraminiferida. Since these slides are not transparent, light should be reflected onto the slide surface from a position above and slightly to the left of the microscope stage. Your instructor will describe the manner in which these fossils have been prepared for study.

   a. Determine the generic name (genus) of as many of the specimens as you can by comparing them with the illustrations in Figure 10.11 and any additional aids provided.

   b. Sketch any three of the genera, and label *aperture, suture,* and *chamber.*

Figure 10.16 Range chart.

Stratigraphic distribution of some genera of the foraminiferida

Periods ⇩	*Genera*											
Quaternary												
Tertiary												
Cretaceous												
Jurassic												
Triassic												
Permian												
Pennsylvanian												
Mississippian												
Devonian												

7. On Figure 10.16, show by means of vertical bars the geologic ranges for *Ammodiscus, Endothyra, Fusulina, Ammobaculites, Globigerina, Bolivina,* and *Quinqueloculina.*

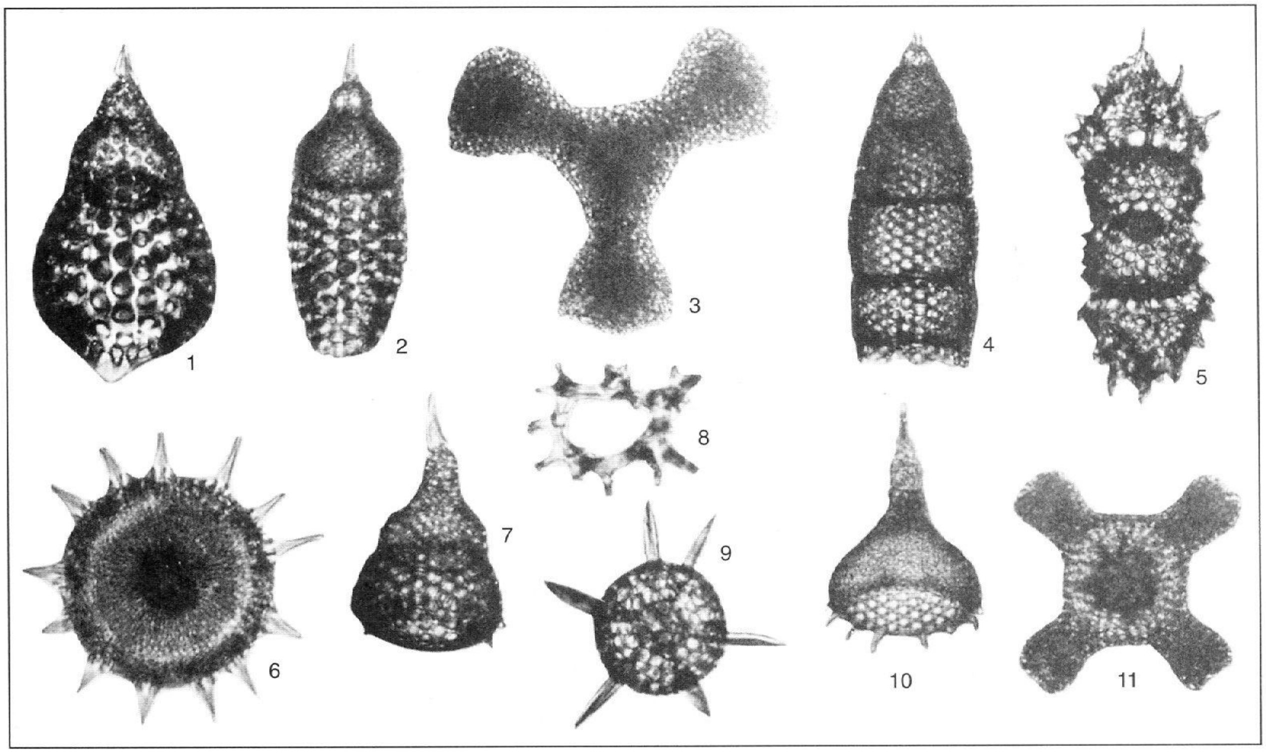
a. What is the maximum possible geologic range for rock containing only *Endothyra?*

b. What is the age of a formation containing both *Robulus* and *Endothyra?*

c. What is the advantage, if any, of having more than one index fossil when making age determinations?

d. Which is the better index fossil, *Fusulina* or *Ammodiscus?* Why?

Figure 10.17 Radiolaria (all magnified 120×). Identification Key: **1.** *Podocyrtus;* **2.** *Theocorys;* **3.** *Dictyostrum;* **4.** *Eucyrtidium;* **5.** *Panartus;* **6.** *Heliodiscus;* **7.** *Lamprocyclus;* **8.** *Dendrocircus;* **9.** *Hexaconthium;* **10.** *Anthocyrtium;* **11.** *Astractura.*



Radiolaria

Radiolaria are planktonic marine microorganisms in which the protoplasm is surrounded by a delicate, often beautifully filigreed skeleton (Fig. 10.17). The skeleton is almost always composed of opaline silica ($SiO_2 \cdot H_2O$). In some regions of the sea, radiolarian tests fall like a microscopic rain upon the sea floor to accumulate as a mucklike deposit called "radiolarian ooze." Because of the increased concentration of carbon dioxide at depths below 4500 meters, the calcareous shells of foraminiferida dissolve, but the siliceous radiolarian skeletons are relatively unaffected and tend to accumulate. The tests of radiolaria are generally modified helmet-shaped or spherical. Some forms, especially those with spherical tests, have long spines projecting from their rims, which may have contributed to buoyancy.

Study Questions

1. How might one interpret the depositional environment of a stratum containing numerous radiolarian fossils but few preserved foraminiferida?

2. Why might radiolarian tests be less likely to be recovered intact from well cuttings than tests of foraminiferida?

3. Examine the slide of radiolaria with the aid of a microscope and substage lamp. Sketch two different genera in the space below.

Sponges

Sponges are primitive multicellular animals belonging to the Phylum Porifera (literally, *pore bearers*). They make up a relatively conservative evolutionary sideline, and have been in existence since the Late Proterozoic (Fig. 10.18). All but one group of sponges are marine, and they inhabit all the seas at all depths from the strand line to the deepest abyss. If they are living in calm water, sponges tend to grow into tall, symmetrical, and bushy forms, but they develop low, encrusting shapes when growing in areas where currents exist. Sponges with skeletal elements composed of calcium carbonate require some sunlight and thus grow at depths of less than 200 m. As might be expected, the siliceous spicule-producing "glass sponges" are tolerant of cold temperatures and great depths. Cold, deep waters may not, however, have been the habitat of ancient glass sponges. In the Devonian of New York and Pennsylvania, for example, glass sponges occur in strata apparently deposited on the sandy bottom of a shallow sea.

Although sponges vary widely in form and size, the basic plan is that of a much-perforated vase with walls modified by folds and canals. Most modifications appear to be a response toward attaining greater food-gathering surface and protecting the feeding cells. The body is attached at the bottom to the sea floor, or it may be connected at the base to lateral tubes leading to other members of the colony (Fig. 10.19). In a simple sponge, there is a central cavity that has an opening **(osculum)** at the top.

The body wall is composed of two layers of cells with a layer of mesenchyme between them. The outer layer consists of hexagonal protective cells, whereas the inner layer is composed of collared flagellated feeding cells **(choanocytes).** Pore cells *(porocytes)* provide openings for water to enter the sponge.

The paleontologically important **spicules** (Fig. 10.20) are secreted by amoeboid cells located in the mesenchyme. The spicules support the body. They also provide criteria for identification and greatly improve the chances for preservation. Spicules may be calcareous or siliceous, single or multiple rayed, or variously modified into pitchfork, tuning fork, or tripod shapes. Some sponges do not secrete mineral spicules but secrete a leathery substance called spongin.

There are five taxonomic classes of Porifera. These are the *Desmospongea, Hexactinellida* (formerly *Hyalospongea*), *Calcarea* (formerly *Calcispongea*), *Sclerospongea* (coralline sponges), and a problematic but important group known by the name *Stromatopora.* Desmospongids have spicules composed of silica, spongin, or both. Hexactinellids have siliceous spicules, whereas the spicules in the calcarids are composed of calcium carbonate.

Figure 10.18 Geologic range of the phylum Porifera. The fossil record for sponges is not an abundant one, but it is of long duration.

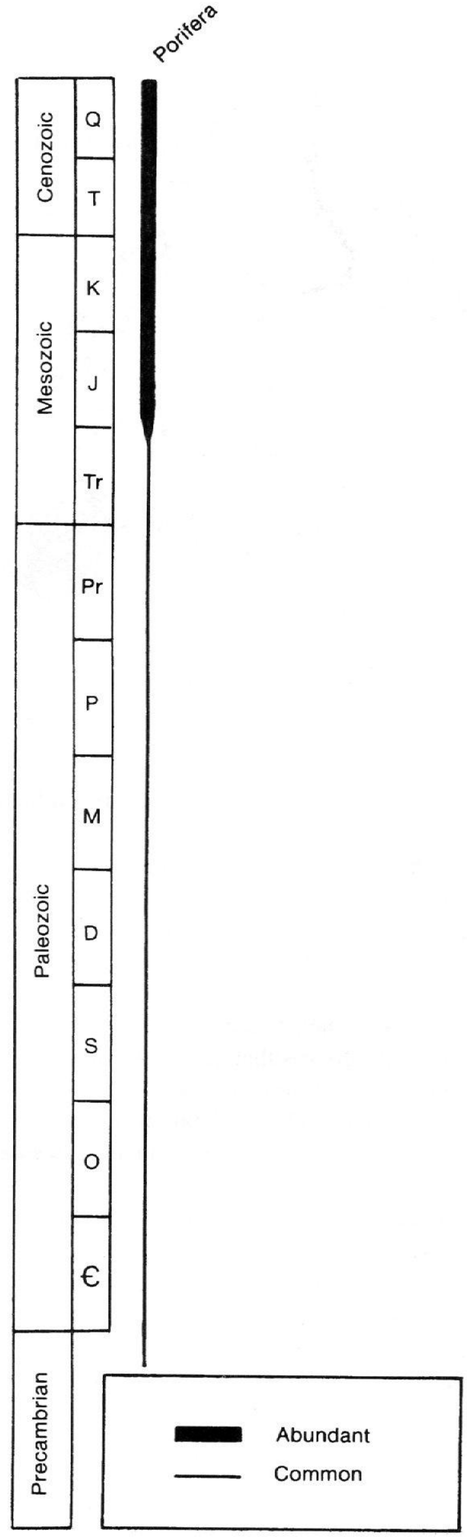
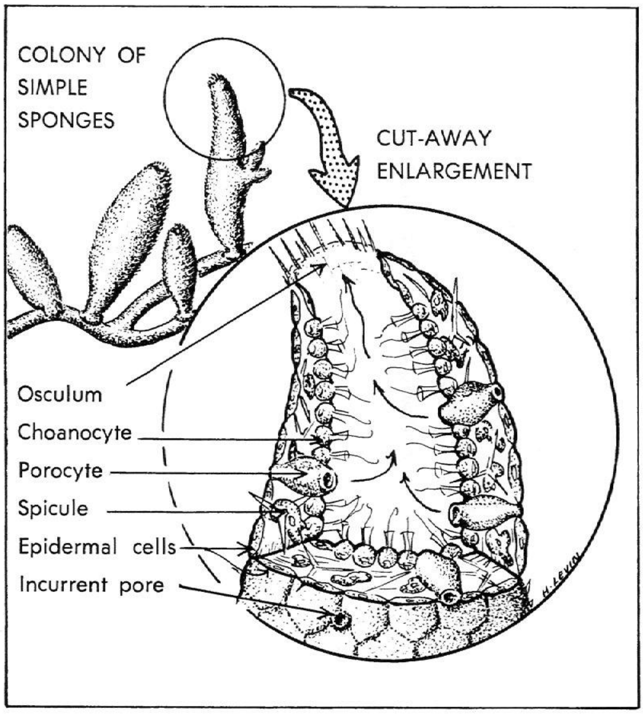


Figure 10.19 Features of a simple sponge.



The stromatoporates (Fig. 10.21) are problematic because they bear a strong resemblance to both sponges and corals. Although they exhibit certain canal and skeletal patterns seen in sclerosponges, stromatoporates (also referred to as stromatoporoids) lack spicules. For this reason, some paleontologists prefer to place them in the Cnidaria along with the corals.

Regardless of their taxonomic placement, stromatoporates are important fossils that grew prolifically in Early Paleozoic seas. Their skeletons consist of fine, closely spaced pillars and partitions. The skeletal structures are so small and intricate that microscopic examination is essential for identification.

The fossil sponges illustrated in Figures 10.20 will help you to identify some of the sponges in your study set. The drawings include one representative of problematic spongelike fossils called *archaeocyathids.* Archaeocyathids built extensive reefs in many tropical areas of the world during the Cambrian. Their cone-shaped skeletons, with perforated double walls and septalike partitions, suggest affinities to both corals and sponges. Archaeocyathids, however, are regarded as sufficiently distinct to warrant their placement in a separate phylum, the Archaeocyatha.

Study Questions

1. How many rays can you count on the spicules of *Astraeospongium?* Might there be additional rays perpendicular to the ones you have counted?

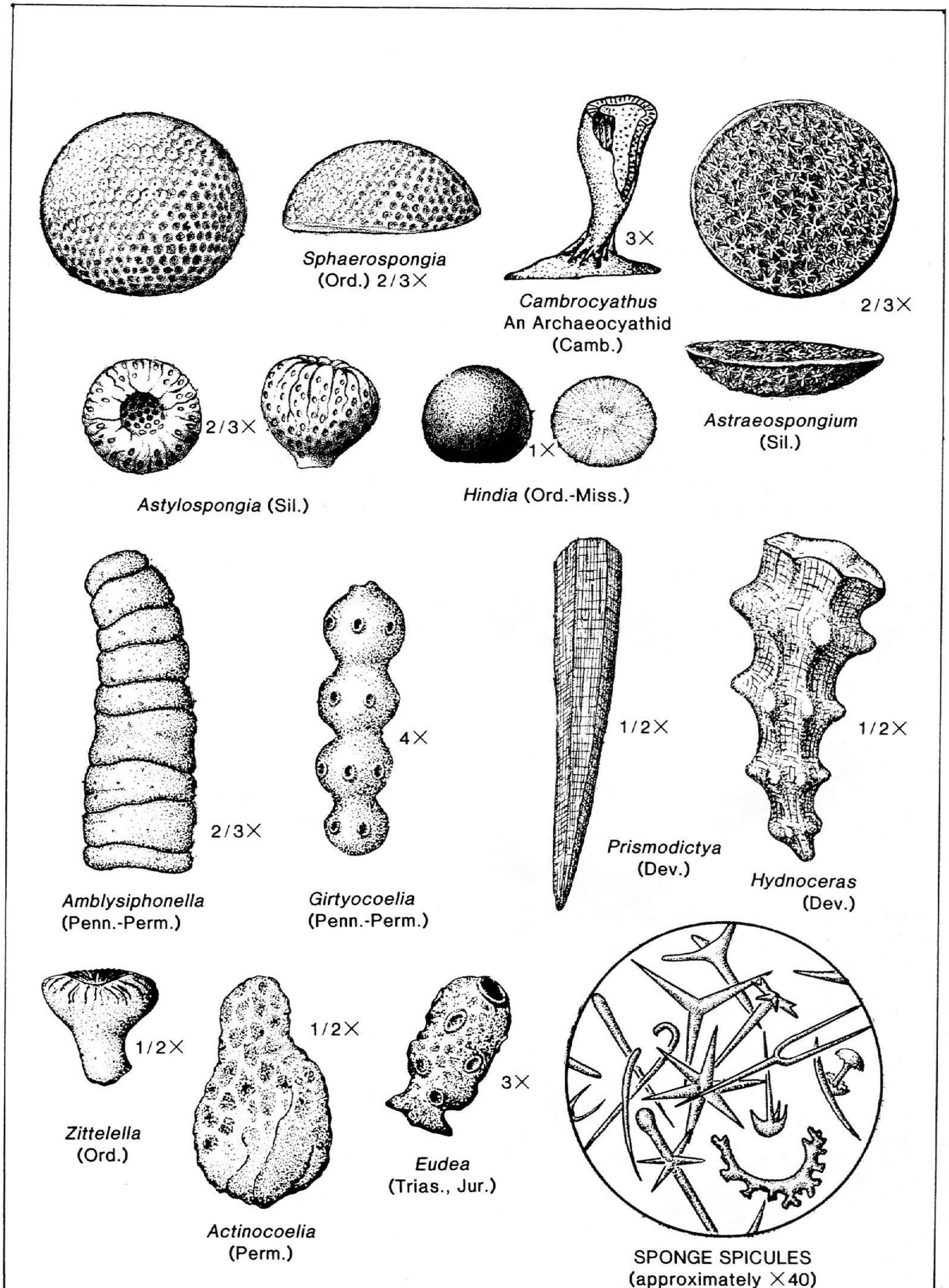
2. In Figure 10.22, what is the age of the stratum above the layer of bentonite (altered volcanic ash)? What is the age of the stratum below the bentonite layer?

3. Was the ash (now bentonite) deposited in a marine or continental environment?

4. Name a characteristic of archaeocyathids that suggested to early investigators that they might be members of the Phylum Porifera.

Figure 10.20 Sponges and spongelike fossils.

Partly from Collinson, C. W., 1959, Illinois State Geological Survey, Educational Series 4.



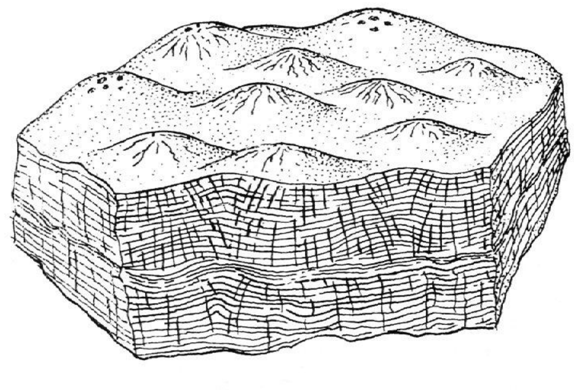
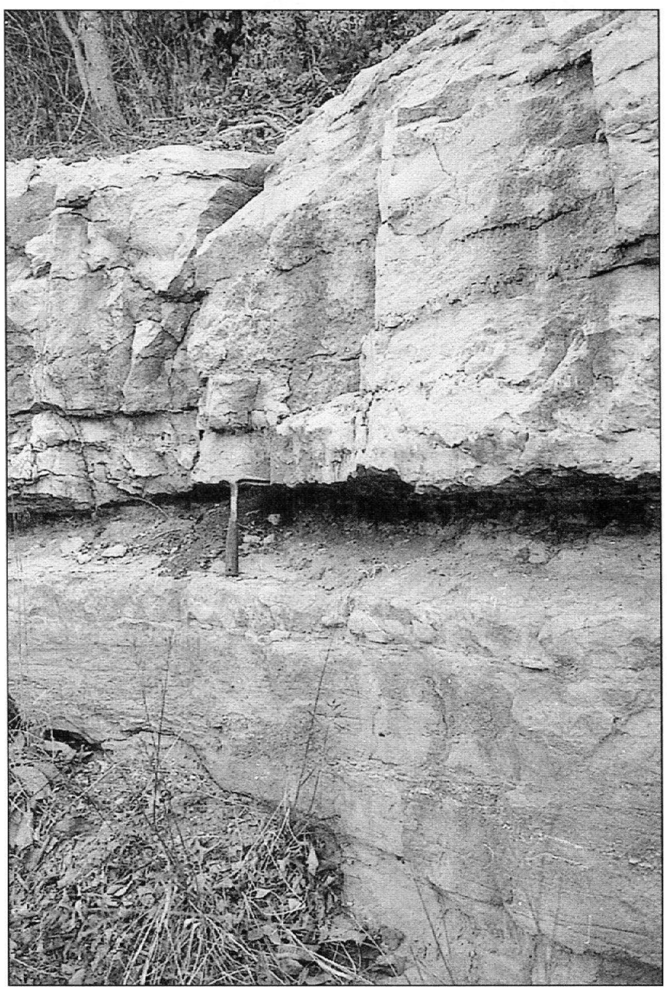


Figure 10.21 Fragment of the stromatoporoid *Actinostroma.* The small raised areas on the top surface are called mamelons, and the rootlike grooves on the summits of the mamelons are termed astrorhizae. Mamelon astrorhizae are probably the skeletal traces of a water-conducting system. Vertical tubes shown on the front and sides of the specimen are astrorhizal canals. (X6)

Figure 10.22 Two beds of limestone separated by an easily weathered layer of bentonite (a clay formed from the alteration of volcanic ash). The geology hammer marks the location of the bentonite layer. The bed above the bentonite layer contains the fossil sponge *Astraeospongium.* The bed below the bentonite layer contains *Zittelella.*



Corals and Related Cnidarians

The Phylum **Cnidaria** (formerly Coelenterata) comprises a large and diverse group of Proterozoic to Recent animals, which include corals, sea anemones, sea fans, the *Hydra,* and the jellyfish (Figs. 10.23 and 10.24). All cnidarians are aquatic, and most are marine. They are characterized by a saclike body, with tentacles around the mouth of the sac. Special stinging cells assist the coelenterate in capturing live food. These cells, called *cnidoblasts,* are a distinctive feature of the phylum.

The body plan assumed by cnidarians may be that of either the polyp or the medusa. In the polyp, the sac is attached to some object at one end, and the mouth and tentacles are at the other. Corals and sea anemones have this form. The medusa or jellyfish form is similar although it is inverted so that the mouth and tentacles lie below the sac (see Fig. 10.24). In some species, both body forms alternate in the life cycle.

Jellyfish are the oldest known fossilized representatives of the Phylum Cnidaria. Earliest finds are Late Proterozoic, and jellyfish have persisted since that time without significant change. Because they have no hard parts, fossil jellyfish are found only rarely, usually as impressions in what was once the soft mud of the sea floor.

Paleontologically, the corals are the most important of the Cnidaria. Corals have been important members of the marine biosphere since the Ordovician (Fig. 10.25). The living coral polyp secretes a calcareous cup **(theca)** in which it resides (Fig. 10.26) and from which it grows upward and outward. If the coral is solitary, the cup often takes a horn shape. Most corals, however, live in colonies composed of great numbers of individual theca bundled together, sometimes saving space in prismatic arrangement. The theca of some corals may be divided by vertical plates **(septa)** that mark the position of deep folds in the body wall of the animal. Septa lend support to the polyp and separate layers of tissue, thus increasing the digestive area. As the animal grows, it partitions off its lower part with horizontal plates called *tabulae.*

Corals are classified on the basis of the nature and arrangement of their septa and other skeletal features. For example, the common Paleozoic "horn corals," Order Rugosa, inserted their septa at only four locations during adult growth, and are therefore called *tetracorals* (see Fig. 10.26). In other Paleozoic corals, the tabulae are the most obvious morphologic feature of the theca, and septa are absent or represented by vertical rows of short spines or low ridges. These are the tabulate corals of the Order Tabulata. They include many colonial forms, such as the so-called "honeycomb" and "chain" corals. (See *Favosites* and *Halysites,* Fig. 10.27.) Both the Tabulata and Rugosa became extinct at the end of the Paleozoic, and most Cenozoic corals are members of the Order Scleractina. They are commonly called *hexacorals* as a reminder of their six-fold septal symmetry.

Figure 10.23 Diversity of living cnidarians.

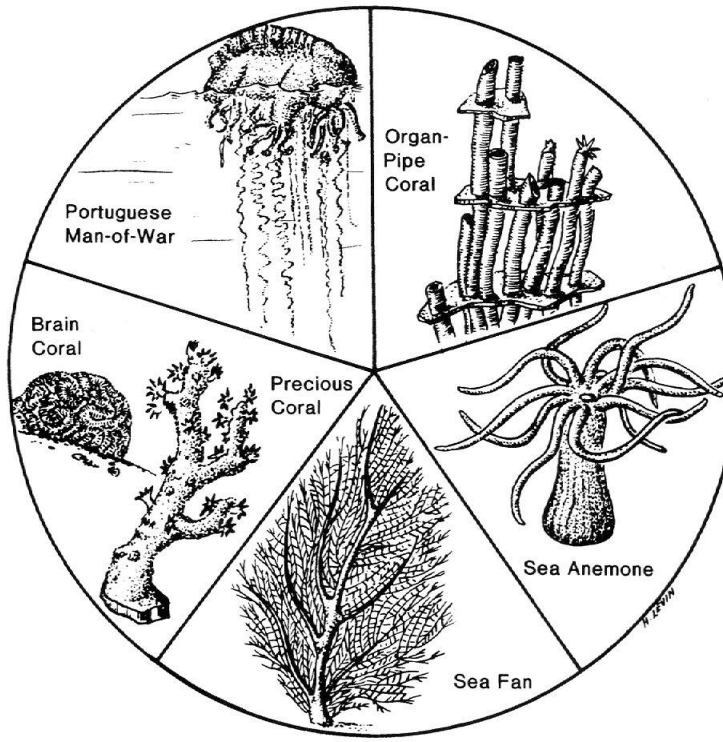


Figure 10.24 (A) Drawing of *Hydra* with section cut away. This tiny, tentacled cnidarian (3 to 10 mm in height) lives in freshwater bodies. As with many other cnidarians it is radially symmetrical. (B) Enlargement of the body wall of *Hydra* to show types of cells. (C) The polyp (left) and medusa (right) body plans of cnidarians. (D) A cnidocyte containing an undischarged nematocyst.

From Levin, H. L., *Ancient Invertebrates and Their Living Relatives*, Upper Saddle River, NJ: Prentice Hall, 1999.

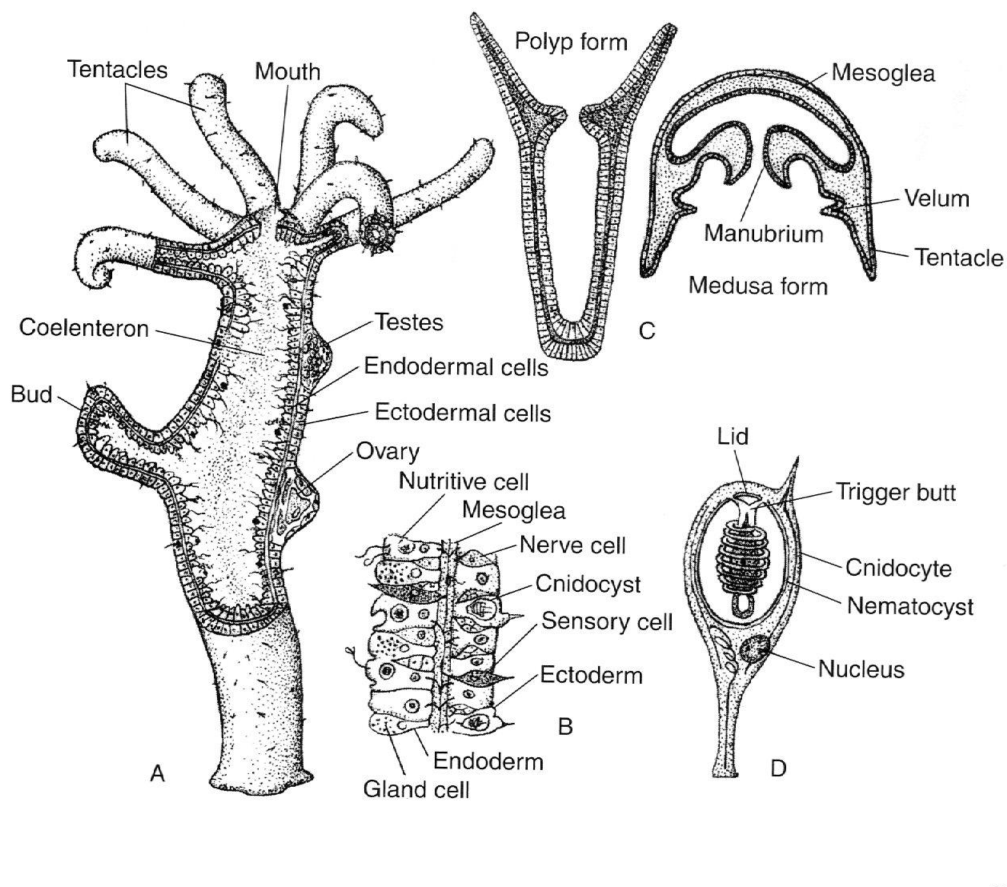


Figure 10.25 Geologic range of some important groups of corals.

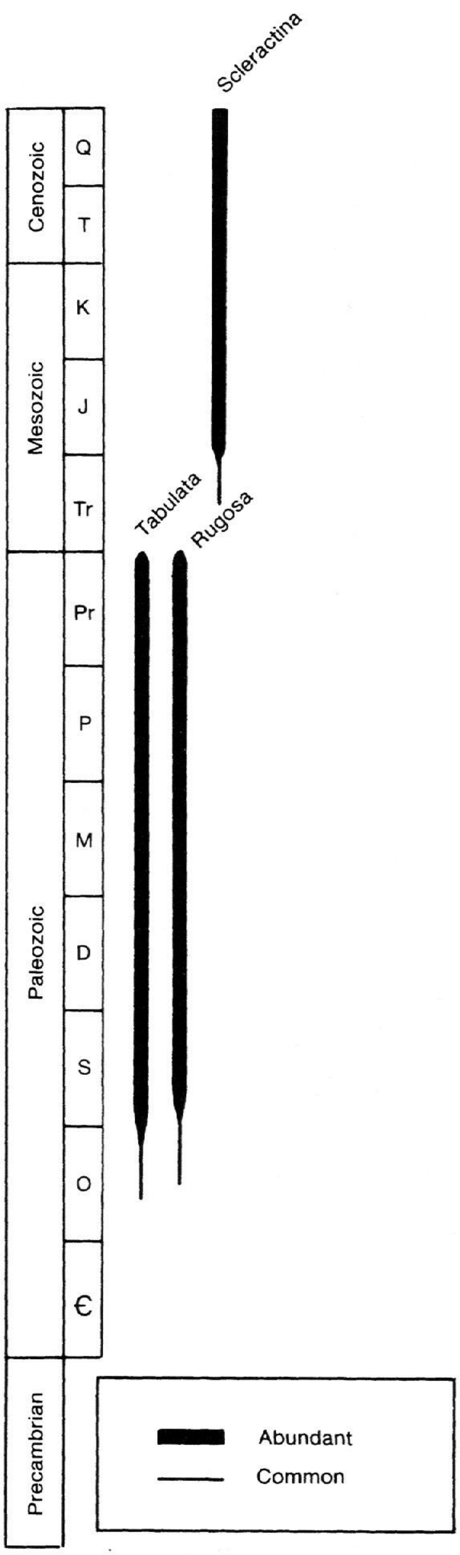
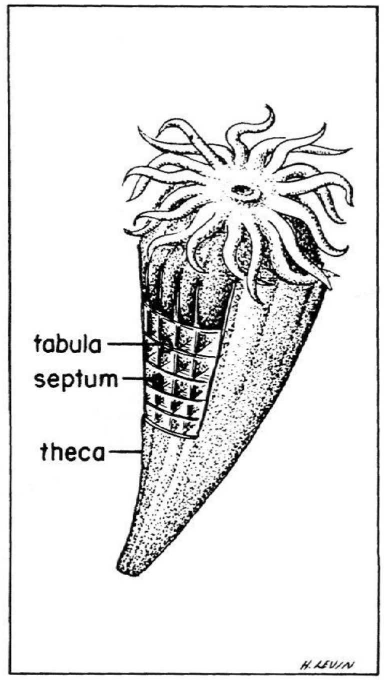


Figure 10.26 Presumed polyp-theca relationship in a Paleozoic horn coral.



Reef corals imply clear (low terrigenous sediment influx), warm, and shallow marine waters. Today, the majority of reef builders live at depths of about 15 m or less. Their optimum temperature preference seems to be between 25°C and 29°C, and this tends to restrict them to latitudes between 30°N and 30°S. Reef corals have a mutually beneficial relationship with algae, called **symbiosis.** This relationship partly accounts for the fact that reefs do not grow at water depths greater than about 30 m because the algae require adequate light for photosynthesis.

Study Questions

1. What function do septa serve in a coral? What is the function of tabulae?

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2. If fossil corals are found in a limestone ledge exposed in the Rocky Mountains at an elevation of 1500 m, what geographic changes must have occurred since the time the corals were living?

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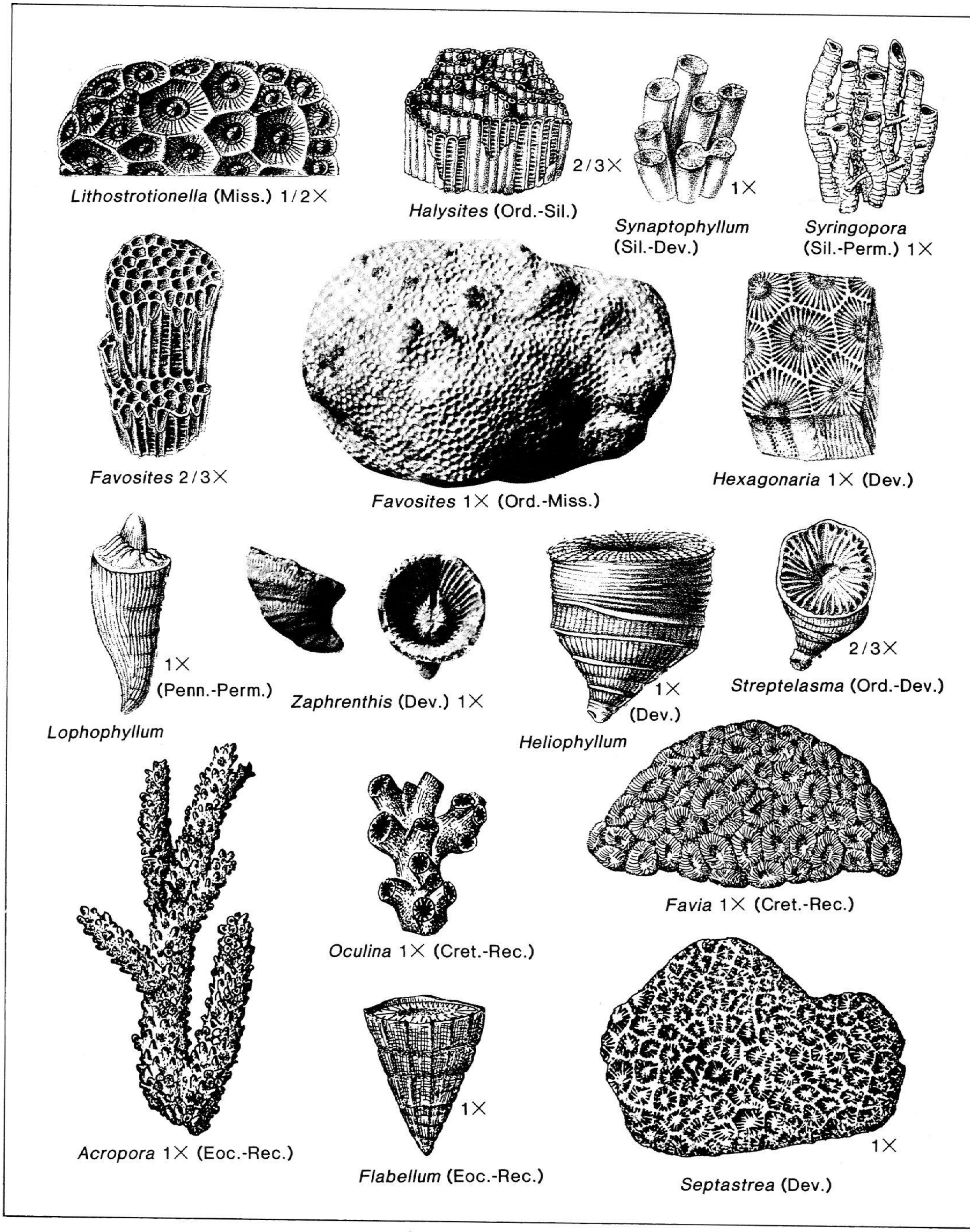
Figure 10.27 Cnidaria.

Partly from Collinson, C. W., 1959, Illinois State Geological Survey, Educational Series 4.



3. Certain Pennsylvanian strata in the Arctic island of Spitzbergen (Lat. 78°N) contain extensive deposits of reef-building corals. From this occurrence, what do you infer about the climate of this region in Pennsylvanian time? On what assumption is this inference based? Is more than one interpretation possible?

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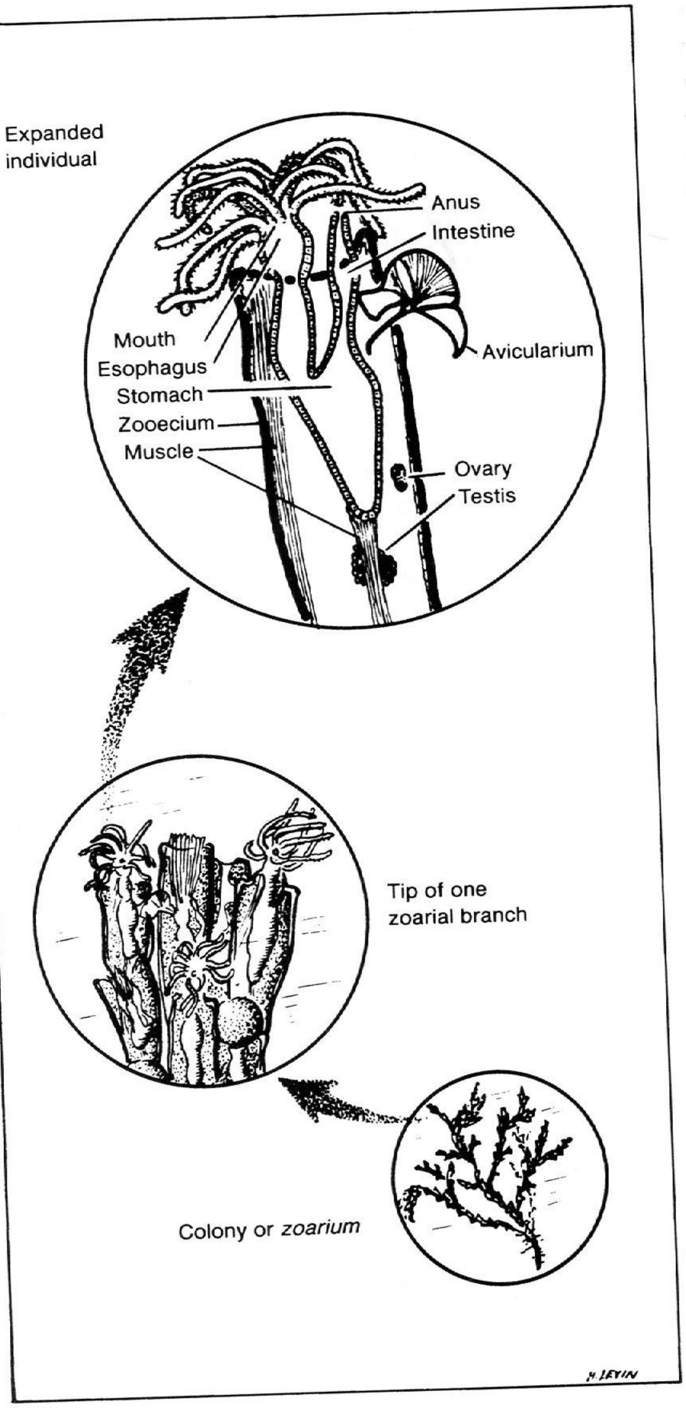
4. Examine the study specimens of recent and fossil corals. In the space below, sketch a tabulate coral, a rugose coral, and a hexacoral. Label tabulae, septa, and theca, and lightly outline a restored profile of a polyp for each coral type.

Tabulata

Rugosa

Hexacoralla

Figure 10.28 Structures of a typical living bryozoan.

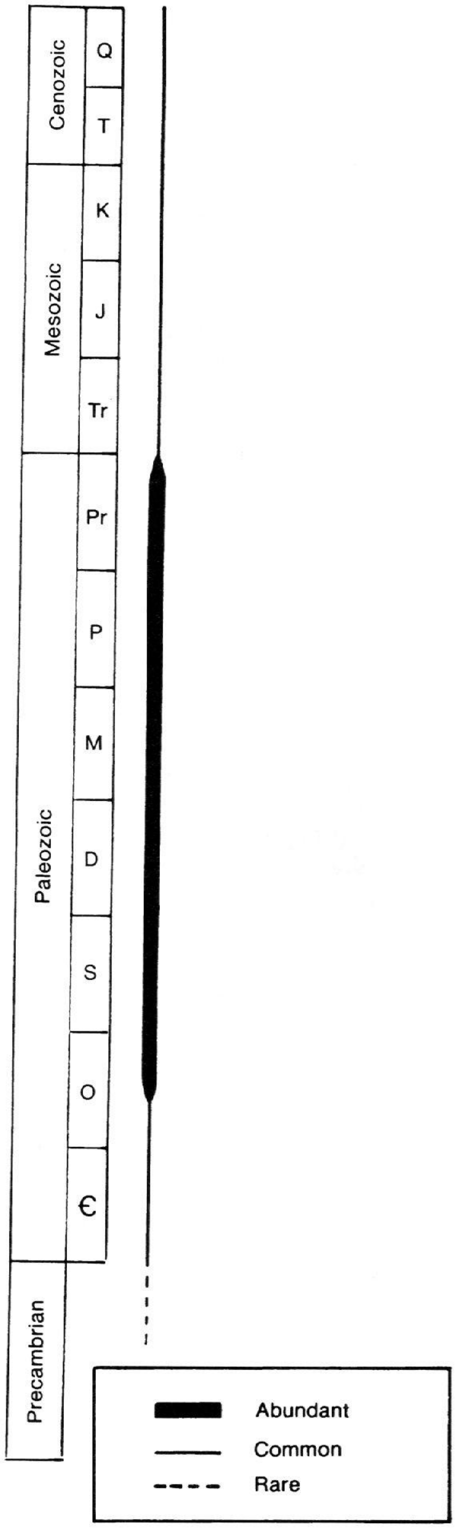


THE BRYOZOA

Bryozoans, now classified as Phylum Ectoprocta, include a large group of animals that grow in colonies, appear mosslike to the naked eye, and bear a superficial resemblance to some Cnidarians. However, the similarity cannot be pressed too far, for a bryozoan has both a mouth and an anus, and a complete V-shaped digestive tract. Most fossil bryozoans secreted a calcareous twiglike, matlike, or frondlike colony called a **zoarium.** Each tiny animal **(polypide)** was housed in a cuplike cavity or **zooecium** (Fig. 10.28). Because of their small size, the zooecia appear as tiny pinpoint depressions on the outside of the zoaria. In most living species, the mouth is surrounded by a horseshoe-shaped structure bearing ciliated tentacles called the **lophophore.**

Fossil bryozoans are abundant in Paleozoic carbonate strata (Fig. 10.29). Because of their small size, thin sections of zoaria must be prepared and examined under the microscope. However, a few of the common forms can be classified into the following artificial categories for recognition in hand specimens.

Figure 10.29 Geologic range of bryozoans.

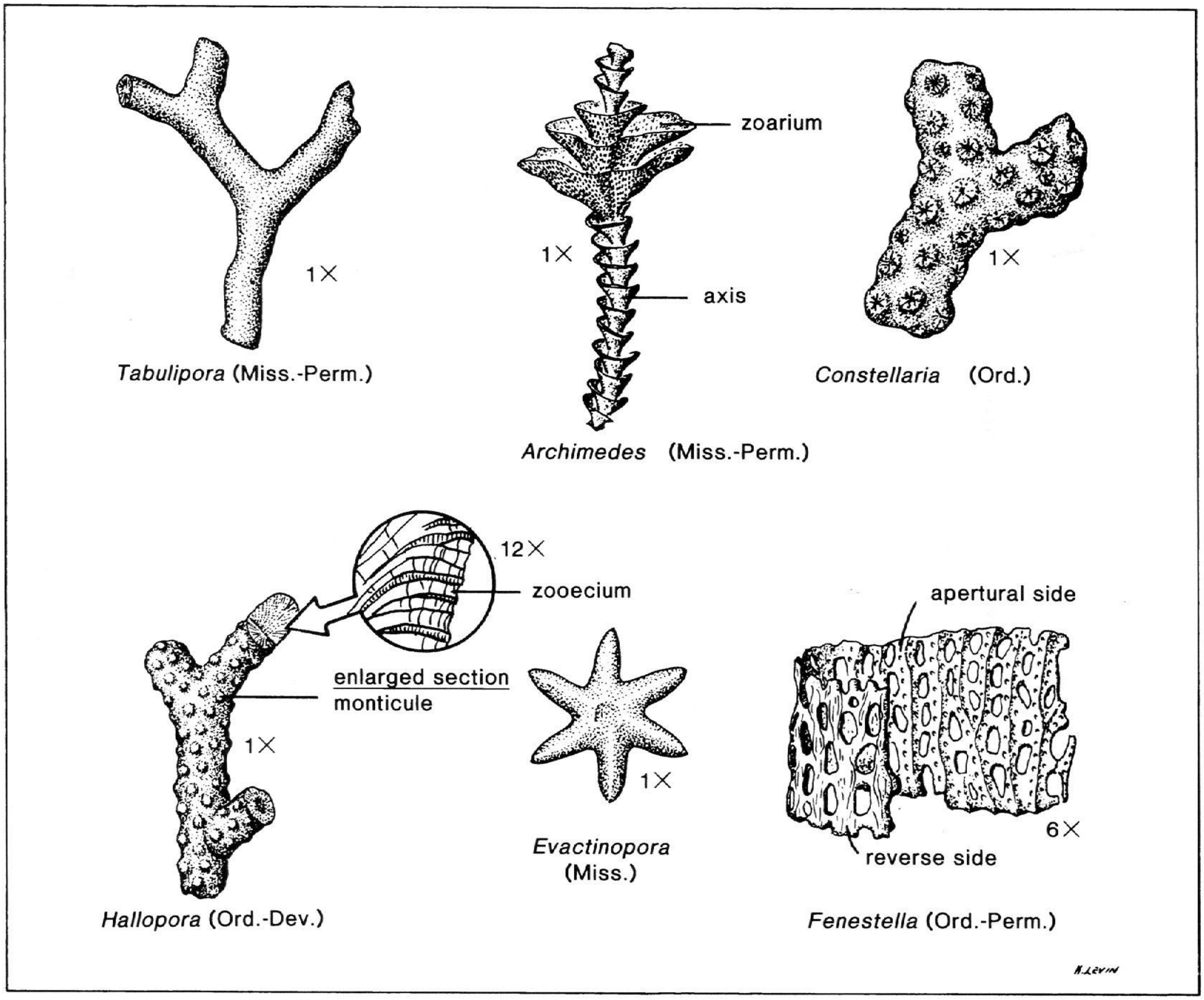


1. The "branching twig" or ramose forms are especially characteristic of rocks of the Ordovician. At first glance, they resemble erect-branching shrubbery with stems about the thickness of pencils. Low mounds, called monticules, and flat areas, called maculae, may be spaced regularly over the surface. The maculae in the genus *Constellaria* have a distinctive star shape (Fig. 10.30). *Hallopora* (see Fig. 10.30) is characterized by abundant nodose monticules.
2. Lacy or *fenestellate* bryozoans appeared in the Silurian and became especially abundant during the Mississippian. A typical genus, *Fenestella* (see Fig. 10.30), rather resembles petrified lace, and is best seen along the weathered surfaces of limestone beds. In these delicate bryozoans, the zooecial openings occur in rows along the vertical branches, and the branches are connected by crossbars (dissepiments). The tiny windows framed by branches and dissepiments are called **fenestrules** (L. *fenestra,* window).
3. Perhaps the most unusual fossil bryozoan is *Archimedes*. Sometimes called the "corkscrew fossil," *Archimedes* consists of a calcareous helicoid spiral that served as the axial support for fronds of lacy bryozoa (see Fig. 10.30). Normally, the fragile fronds are broken away, and only the axis can be collected. The generic name is derived from the axial spiral, which resembles the "Archimedes Screw," by which that famous Greek is presumed to have lifted water from wells. Although most prevalent in Mississippian strata of eastern and central North America, *Archimedes* migrated slowly westward, reaching Russia by the Permian.
4. Another unusual shape in bryozoans is seen in the star-shaped *Evactinopora* (see Fig. 10.30). It is a common fossil in the Mississippian rocks of the central United States.

Study Questions

1. Study the specimens of fossil and living (preserved) bryozoans. Sketch the specimens designated by your instructor, and note the position of a zooecium on each drawing by an arrow.
2. Compare the size of a zooecium in a "branching twig" bryozoan with the theca of a colonial tabulate coral. Is size a useful means for distinguishing bryozoans from corals?

Figure 10.30 Fossil bryozoa. Individual zooecia are represented by the tiny dots on *Tabulipora* and *Evactinopora,* and by the small pits adjacent to large fenestrules in *Fenestella.*



3. What advantage, if any, do fenestra provide to the polypides of a bryozoan like *Fenestella?*

4. *Archimedes* and most other bryozoans live sedentary lives on the sea floor. How then did they spread from one place to another?

5. What organs present in the coelum of a bryozoan are **not** present in the coelenteron of a coral polyp?

THE BRACHIOPODA

Brachiopods have been inhabitants of the earth from the Late Proterozoic and Early Cambrian to the present (Fig. 10.31). During the Paleozoic, however, they were far more abundant and diverse than today. On first seeing a fossil brachiopod, one is reminded of the two parts or valves of a clam shell. However, closer examination shows that the two valves of a brachiopod are not identical, as is the case with most common clams. The valves of a brachiopod (Fig. 10.32) are designated **pedicle** (ventral) and **brachial** (dorsal), whereas those of a clam are referred to as right and left. In the articulate brachiopods, the valves are hinged along the posterior edge by teeth and sockets. Inarticulate brachiopods lack a definite hingement, the valves are held together only by muscles, and the shell is composed of a mixture of calcium carbonate and an organic horny substance called chitin.

Most brachiopods attach themselves to the sea floor by a fleshy stalk or **pedicle** (see Fig. 10.33). In the inarticulate group, the pedicle simply emerges between the two valves, whereas in articulate brachiopods, the pedicle emerges from an opening (the **pedicle opening**). In most articulates, the valves are composed of calcium carbonate and are variously ornamented by concentric growth lines and radial ridges **(costae)** or threadlike ridges called **costellae.** Some forms developed a midradial fold on one valve, with a trough **(sulcus)** in a corresponding position on the other valve. These radial and concentric features probably served to strengthen the shell and aided in directing water movement into and out of the shell.

Among the more conspicuous soft parts within the valves is the **lophophore.** The lophophore (Fig. 10.33) consists of two coiled ciliated tentacles whose function is to keep the water between the valves in circulation, so as to distribute oxygen throughout the tissues and remove carbon dioxide. The water currents generated by the cilia on the lophophores also direct suspended food particles in toward the mouth, from which the food passes into the stomach and intestine.

Modern brachiopods are exclusively marine and occur at most water depths in all latitudes. However, they are not common, and tend to occupy a subordinate position in the seas. Even if this were not true, comparative ecological studies between living and fossil brachiopods would be difficult because modern forms are not sufficiently similar to most extinct forms. One exception is found in the inarticulate brachiopod *Lingula,* which has the distinction of being probably the oldest known genus in the animal kingdom. Species of this genus are found today in the Pacific and Indian Oceans. They prefer warm or tropical waters of subnormal salinity, and live at depths less than 183 m. The shells of living *Lingula* (see Fig. 10.33) are similar to those of fossil *Lingula* in Cambrian rocks over 500 m.y. old.

Figure 10.31 Geologic range of the phylum Brachiopoda.

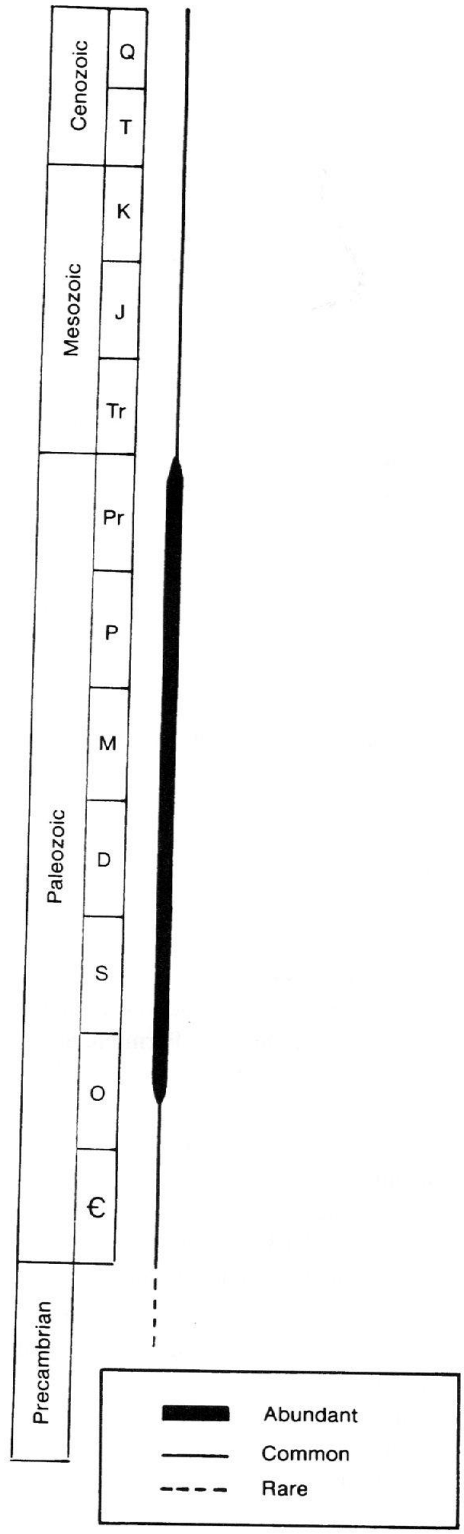


Figure 10.32 Features of brachiopod valves. The brachiopod depicted is *Cererithyris*, a terebratulid of Jurassic age.

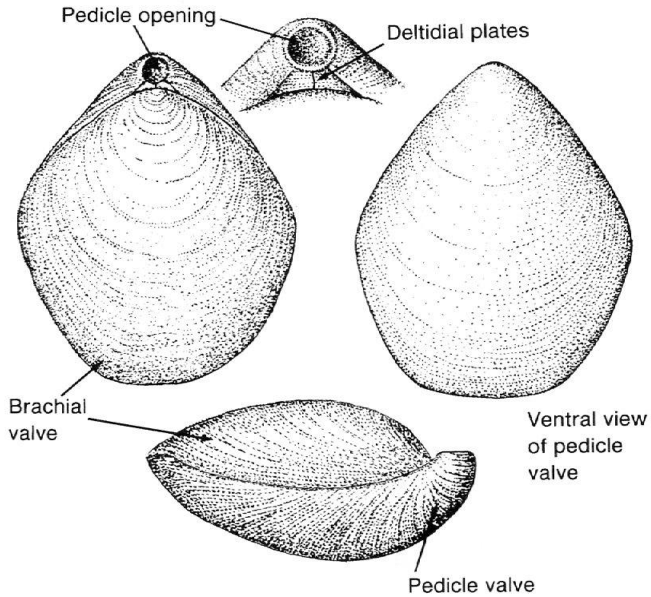
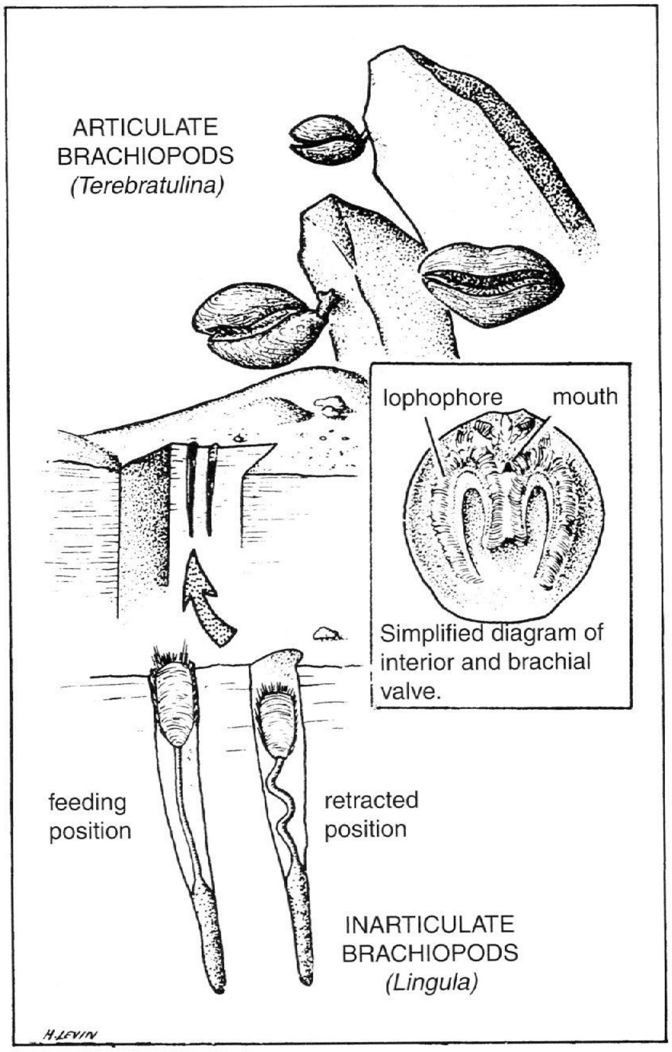


Figure 10.33 Recent brachiopods.



The articulate brachiopods quickly surpassed their linguloid relatives in numbers and diversity. Because of their rapid rate of evolutionary change, they are excellent **index fossils.** The more common articulates can, for convenience, be referred to one of the groups listed below. Each group is taxonomically equivalent to an order or suborder of the Phylum Brachiopoda.

1. **Orthids** Subcircular, flatly biconvex brachiopods with straight hinge line and radial ornamentation. Geologic range: Cambrian to Permian, abundant in Ordovician. Representative genera are *Platystrophia* (Fig. 10.34), *Enteletes* (Fig. 10.34), and *Hebertella* (Fig. 10.35).
2. **Pentamerids** Biconvex, often smooth, thickly rounded, elongate forms with short hinge line as in *Pentamerus* (Fig. 10.35). Geologic range: Middle Cambrian to Late Devonian, abundant in Silurian.
3. **Strophomenids** Compressed forms with straight hinge lines and usually fine radial ornamentation (costellae). Geologic range: Ordovician to Late Jurassic, abundant in Ordovician and Devonian. Typical genera are *Strophomena, Sowerbyella, Rafinesquina* (Fig. 10.34), and *Leptaena* (Fig. 10.35).
4. **Spiriferids** The interior of the brachial valve of the spiriferid contains a calcareous **helicoid** coil, which in life surrounded the lophophore (as in *Mucrospirifer,* Fig. 10.34). Because the coil extends laterally, the enclosing valves are elongated laterally and give many of the spiriferids a winglike appearance. Geologic range: Middle Ordovician to Late Jurassic, abundant in Devonian. Other representative genera are *Platyrachella* (Fig. 10.35) and *Cyrtina* (Fig. 10.34).
5. **Atrypids** Atrypids are also spire-bearing but differ from spiriferids in the direction of coiling of the spiral. In atrypids, the axis of coiling is in the dorsal-ventral (up and down) direction and not parallel to the hinge line. As a result, atrypids develop hemispherical brachial valves to accommodate the coil. Geologic range: Middle Ordovician to Early Mississippian, abundant in Devonian. *Atrypa* is a typical and abundant representative of this group (Fig. 10.35).

Figure 10.34 Fossil brachiopods.

From Collinson, C. W., 1959, Illinois State Geological Survey, Educational Series 4.

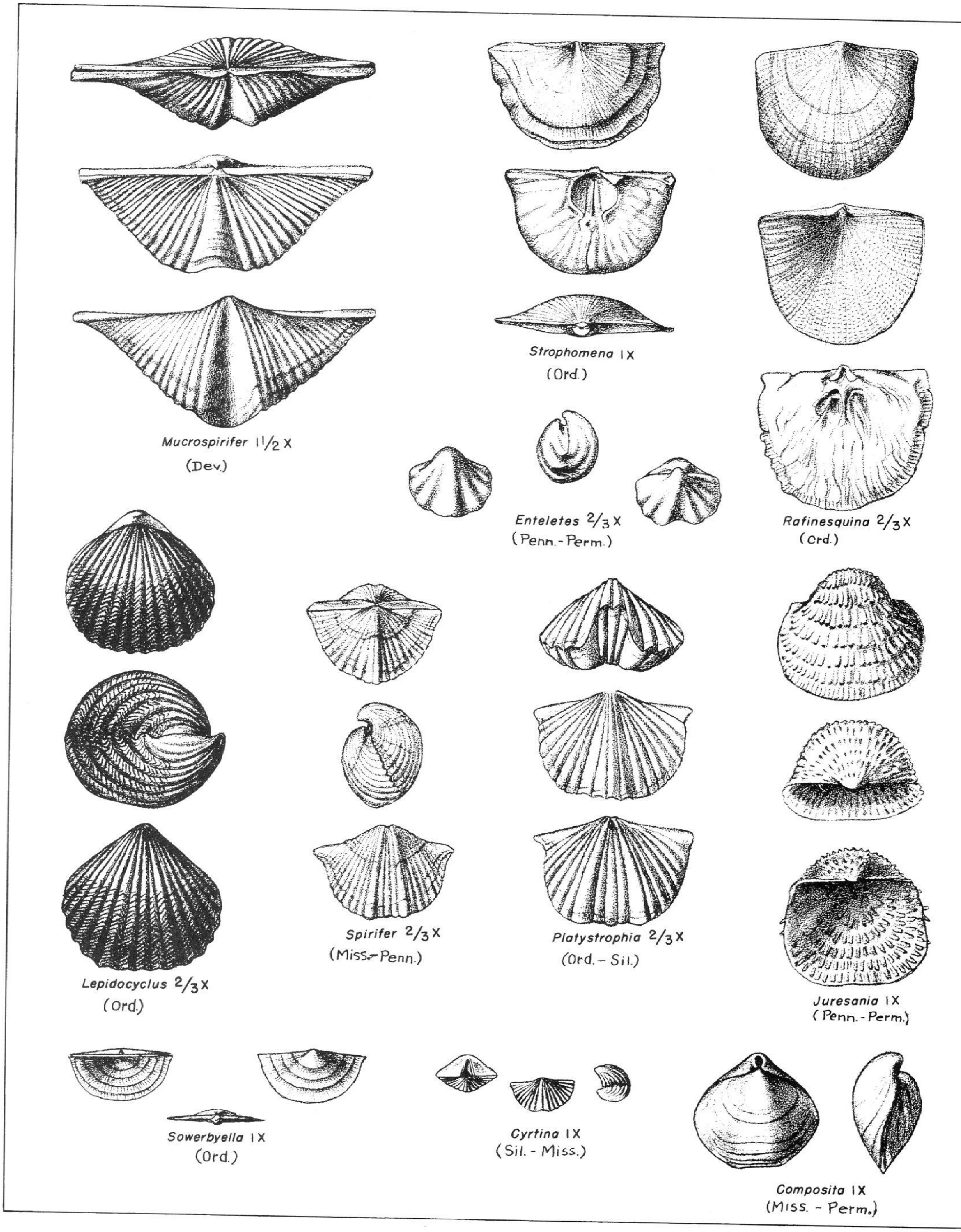
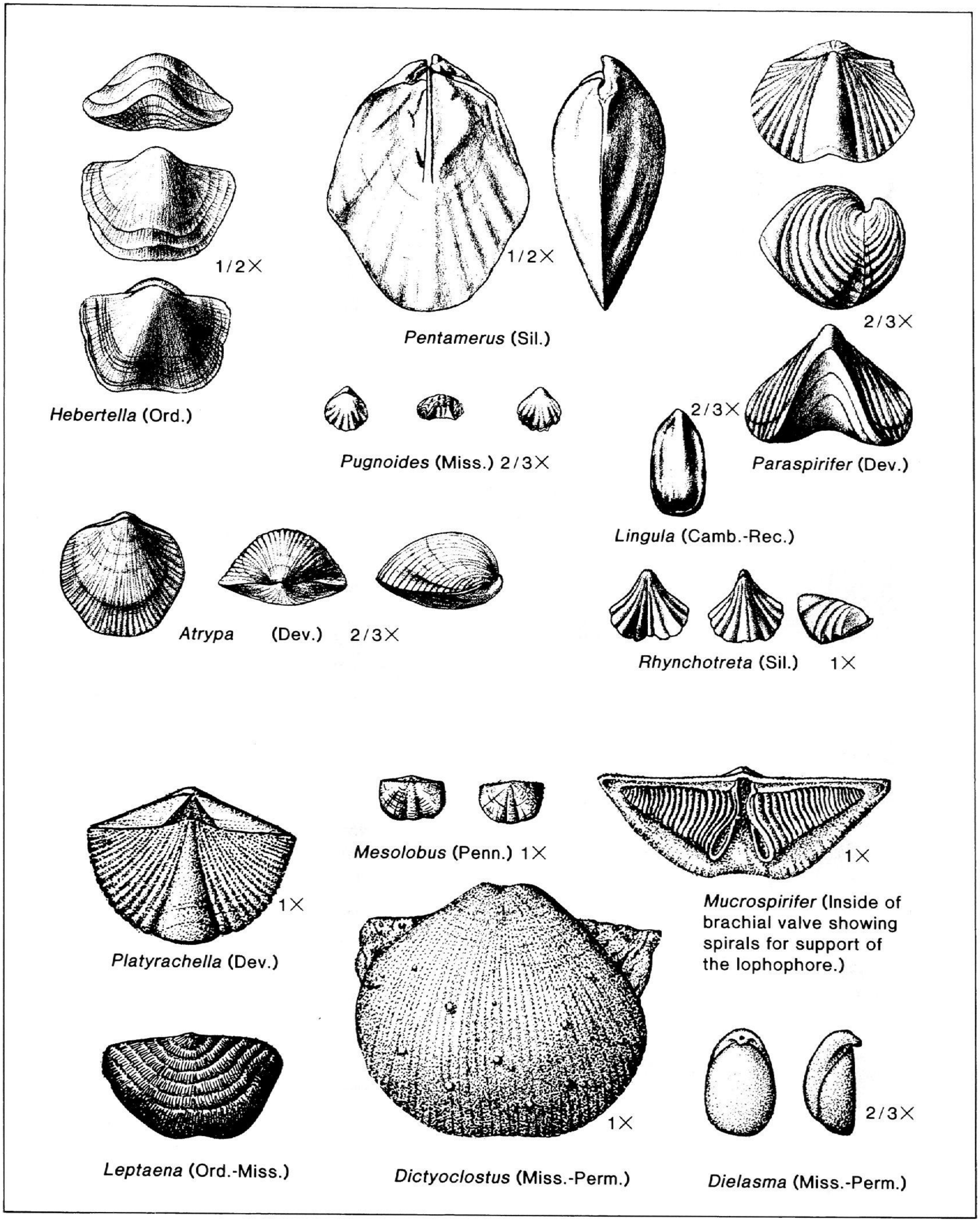


Figure 10.35 Fossil brachiopods.

Partly from Collinson, C. W., 1959, Illinois State Geological Survey, Educational Series 4.



6. **Athyridids** These forms are characterized by an elongate beak and an internal spiral of the atrypid type. The shell is mostly biconvex and lacking in strong radial ornamentation. Geologic range: Late Ordovician to Jurassic, abundant in Mississippian and Pennsylvanian. A typical and common genus is *Composita* (Fig. 10.34).
7. **Productids** The most characteristic features of productids are the conspicuous spines and broken spine bases located over the general exterior surface of the valves or along the hinge line. The larger forms possess flattened or slightly concave brachial valves and strongly convex pedicle valves. Geologic range: Late Ordovician to Late Permian, abundant in Mississippian through Permian. *Juresania* (Fig. 10.34) and *Dictyoclostus* (Fig. 10.35) are representative genera.
8. **Rhynchonellids** Rhynchonellids are strongly beaked forms, usually with strong, accordionlike plications extending radially from the beak. The shells are triangular to rounded in outline, and the hinge line is short. Geologic range: Middle Silurian to Recent, abundant Ordovician through Mississippian and in Jurassic. *Lepidocyclus* (Fig. 10.34), *Pugnoides,* and *Rhynchotreta* (Fig. 10.35) are representative of this group.
9. **Terebratulids** In terebratulids, the lophophore is supported by calcareous loops. Most species have the pedicle opening located within the overhanging beak, and although some are costate, most are smooth and have a streamlined appearance. Geologic range: Devonian to Recent, abundant in Devonian, Jurassic, and Cenozoic. The living *Terebratulina* (Fig. 10.33) and the fossil *Dielasma* (Fig. 10.35) are representative.

Certain of the brachiopod groups characterize rocks of particular geologic periods. For example, a stratum containing abundant orthids and strophomenids is likely to be Ordovician in age. If pentamerids are common, one would suspect the stratum to be Silurian. Spiriferids tended to dominate brachiopod faunas during the Devonian, whereas productids characterized the post-Devonian periods of the Paleozoic. The Late Permian was a time of widespread extinction among brachiopods, and in the Mesozoic, terebratulids and rhynchonellids predominated. Terebratulids and species of *Lingula* persist into the modern world.

Study Questions

1. Examine the valves of a brachiopod and a clam such as *Mercenaria* (see Fig. 11.4). Which of these bivalved invertebrates has identical valves?

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In which animal does the plane of symmetry cross the valves and hinge line through the beaks?

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2. How would you evaluate the genus *Lingula* as an environmental indicator?

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3. By comparing the specimens in the study set with the illustrations, try to identify the brachiopods as to genus. For specimens that do not closely resemble one of the illustrations, assign one of the group names on the basis of the verbal descriptions. Write your identifications on a separate sheet.
4. Sketch a side and top view of one of the brachiopods in the study set and label the brachial valve, pedicle valve, radial markings, concentric markings, fold, and sulcus. On which valve is the sulcus usually located in your study specimens? Which valve is usually larger?

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5. A clam shell is opened automatically by the elasticity of a ligament along the hinge line. At rest, the clam is open. Articulate brachiopods open their valves by contracting a pair of diductor muscles, and work must be performed to keep the valves agape. How do these two different valve mechanisms affect the way clams and brachiopods appear as fossils? Are you able to find any evidence in support of your answer in the study set?

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6. What would be the probable age (geologic system) of limestone strata containing the following brachiopods?
   a. *Mucrospirifer, Platyrachella,* and *Paraspirifer?*

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   b. *Strophomena, Sowerbyella, Rafinesquina,* and *Hebertella?*

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   c. *Pentamerus, Rhynchotreta,* and the sponge *Astraeospongia?*

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7. Invertebrates of what phylum, other than members of the Brachiopoda, possess a lophophore?

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8. During what geologic period or periods were the following brachiopod groups particularly abundant?

Orthida ______________________

Strophomenida ______________________

Pentamerida ______________________

Productidina ______________________

Spiriferida ______________________

TERMS

algae Informal name for a group of photosynthetic mostly aquatic Protista that range in size from microscopic single cells to large unicellular forms like seaweeds. Diatoms and coccolithophores are unicellular algae.

aperture (on **foraminiferida**) The relatively large opening at the surface of the last formed chamber.

benthonic (or **benthic**) Marine life that are bottom-dwelling.

brachial valve Valve of a brachiopod to which the calcareous supports for the lophophore are attached. Typically, the brachial valve is the smaller valve and may have a small beak.

brachiopoda Marine invertebrates whose shells are composed of two valves that are oriented as dorsal (brachial) and ventral (pedicle).

bryozoa A phylum of colonial, mostly marine, tiny animals that bear lophophores and build calcareous skeletal structures.

carbonization A type of fossil preservation in which most of the organic matter is decayed, leaving a thin carbon-film impression of the organism.

cast A replica of an organism or part of an organism, formed when sediment fills a mold of that organism.

choanocyte Special cells lining the internal cavity of a sponge, and characterized by a delicate collar of protoplasm through which passes a flagellum.

cnidaria A phylum of marine invertebrates characterized by a hollow body cavity, radial symmetry, and stinging cells. (Includes jellyfish, corals, and anemones.)

coccoliths The calcareous plates that form the external covering of a coccolithophore.

coccolithophores Marine, planktonic, biflagellate, golden-brown algae that typically secrete coverings of discoidal calcareous platelets called **coccoliths.**

coccosphere The mineralized preservable shell of a coccolithophore.

costae Radially arranged prominent ridges on the surface of bivalved invertebrates.

costellae Radially arranged striae or fine ridges on the surface of bivalved invertebrates. Costellae are smaller and less prominent than costae.

diatoms Microscopic golden-brown algae that secrete a delicate siliceous *frustule* (shell).

discoasters Calcareous, often star-shaped or radiate, microscopic structures believed to be secreted by certain coccolithophores.

fenestrules Window-like openings that give a lacy-like appearance to colonies of fenestellate bryozoans.

foraminifers Informal name for the Order Foraminiferida, consisting of mostly marine, unicellular animals that secrete **tests** (shells) of calcium carbonate.

fossil The remains or evidence of the existence of organisms that lived in the geologic past.

helicoid Formed or arranged in a spiral.

index fossil A fossil that identifies and dates the strata or succession of strata in which it is found. Also called a *guide fossil.*

lophophore A coiled or lobed ciliated appendage extending from the mouth area in brachiopods and bryozoans. The lophophore's function is primarily feeding.

mold An impression or imprint of an organism (or part of an organism) that is left in sediment or rock.

osculum Large opening in a sponge that makes possible the outward flow of water from the internal cavity to the exterior.

pedicle Fleshy stalk by which a brachiopod attaches itself to a substrate.

pedicle opening Opening along or adjacent to the brachiopod hinge that serves for emergence of the pedicle.

pedicle valve (of **brachiopod**) The brachiopod valve, by convention considered ventral, to which the pedicle is attached.

permineralization A mode of fossilization in which voids in an organic structure, such as bone, are filled with mineral matter.

petrification The general process of converting organic matter such as bone, shell, or wood into a durable substance such as calcium carbonate or silica.

planktonic (or **planktic**) Free-floating, mostly microscopic aquatic organisms.

polypide The individual bryozoan animals (also called a zooid).

radiolaria Protozoans that secrete delicate, often beautifully filigreed skeletons of opaline silica.

receptaculitids Paleozoic, discoidal, perforate calcareous fossils having skeletal elements in spiral rows.

replacement A fossilization process by which the original hard tissue is replaced after burial by inorganically precipitated mineral matter.

septa Partitions that support the vertical mesenteries in the theca of corals and that separate the chambers in cephalopods and foraminifers.

species A group of organisms, either plant or animal, that may interbreed and produce fertile offspring having similar structure, habits, and functions.

spicule A minute calcareous or siliceous structure, having highly varied and often characteristic forms, occurring in and serving to stiffen and support the tissues of various marine invertebrates.

sulcus A concave longitudinal depression on the surface of either valve of a brachiopod.

sutures Lines formed by the intersection of septa with the inner wall of cephalopod conchs or foraminiferida chambers.

symbiosis The relationship that exists between two different organisms that live in close association, with at least one being helped without either being harmed.

test Term that refers to the skeletons of protozoans and certain other animals.

theca The cuplike or tubular skeleton structure that surrounds the polyp of corals.

zoarium The skeleton of an entire bryozoan colony.

zooecium (in **Bryozoa**) The calcareous or chitinous skeleton of an individual bryozoan.