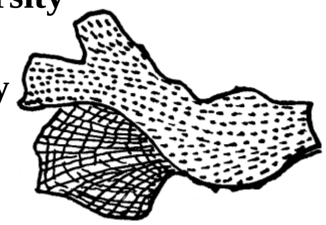
Name________________________________ Date___________________

Stanford Earth Young Investigators: Biodiversity

Lab 02 – Common Paleozoic Fossils

Modified From GS 123 Lab by Will Gearty



Objective: The purpose of this lab is to become familiar with the types of invertebrates common in the Paleozoic. In this exercises, we'll focus on the corals, brachiopods, bryozoans, and sponges. Of course, mollusks, echinoderms, and several other groups were also present and common in the Paleozoic, but we will devote later labs to them because they are abundant and diverse throughout the fossil record and, in the case of the mollusks, particularly diverse in the Mesozoic and Cenozoic. Besides learning about their morphology (form & structure), you should be thinking about paleoecology–the relationships and interactions between the different organisms and between organisms and their environment.

Phylum Porifera (sponges)

Sponges are abundant and diverse (ca. 10,000 species) components of the marine biota. There are also a few freshwater sponges, but these are rare. Sponges occur at all depths, but many species harbor photosynthetic symbionts, restricting them to shallow water environments.

The basic organization of the sponge body is that of a vase. The (relatively thin) walls contain an outer layer of epidermis-like cells, and inner layer of flagellated cells (**choanocytes**), and an intervening **mesohyl**, in which various types of undifferentiated amoeba-like cells and cells that secrete the skeleton float in an organic matrix that is largely non-cellular. Pores (**ostia**) in the wall allow water to flow into the central cavity (**spongocoel**) and out the large opening (**osculum**) at the top of the vase–water flow is facilitated by the beating of choanocyte flagella. Water flowing through the sponge cavity supplies food particles and a medium for gas exchange. Some sponges have a complex internal organization, but even the most labyrinthine species are simply elaborations of the basic vase-like structure.

Sponges form skeletons within the mesohyl. In some cases, these skeletons are made of proteinaceous **spongin** (think of bath sponges) and are unlikely to enter the fossil record. In other cases, however, sponges secrete **spicules** of silica (SiO_2) or calcite ($CaCO_3$) that make preservation likely. Within the sponges, individual clades have repeatedly evolved the ability to precipitate more massive calcareous skeletons. These sponges are well represented in the geological record and include important reef builders, especially in pre-Cretaceous strata.

Systematic Biology

Archaeocyatha: Sponge-like Cambrian organisms. Cup-like calcareous skeleton with a double wall; inner and outer walls full of pores, connected by vertically oriented septa; with or without horizontally oriented tabulae in intervallum; holdfast; solitary or colonial (these were part of the last specimen lab).

Hexactinellida: Glass sponges; spicules of silica (triaxons), sometimes fused to form rigid skeletons.

Demospongea: Skeletons of spongin and/or silica; siliceous spicules monaxons or tetraxons. They make up 95% of extant sponge species. *Cliona*, the common boring sponge, is a demosponge.

Calcarea: Sponges with spicules of calcite or solid calcitic walls; without spongin.

Sclerospongea: Skeleton with both calcareous and siliceous spicules or just spongin, overlain by massive laminate calcareous skeleton. Minor today, but important in pre-Cretaceous as **stromatoporoids**.

Traditional phylogenies treat the Porifera as monopyletic, but recent molecular studies and some ultrastructural features support the hypothesis that the silica-precipitating sponges form a monophyletic group that is sister to the Calcarea plus other animals. The relationship of archaeocyathids to extant sponge classes is uncertain.

Geological History

Based on their phylogenetic position, one might expect to find sponges among the earliest animal assemblages, but in fact, few unambiguous sponge fossils are known before the Cambrian. *Molecular fossils* thought to be of poriferan origin are common in latest Proterozoic organic matter and one presumed sponge body fossil has been reported from the Ediacaran succession in Australia. *Siliceous spicules* first occur in sediments just below the Proterozoic-Cambrian boundary in Mongolia.

In contrast, sponge remains are common in Cambrian assemblages. Siliceous spicules are widespread and morphologically diverse, *sponge body fossils* are well known from the Burgess Shale and its Early Cambrian counterparts, and the Archaeocyatha are conspicuous components of Early Cambrian reefs. Actually, archaeocyathids were principal framework builders in relatively few of these reefs – most were reef dwellers living in reefs built mainly by microbial communities. Although abundant and widespread in the Early Cambrian, archaorcyathids disappeared almost entirely during an episode of extinction near the end of the Early Cambrian; only a few species are known from younger Cambrian deposits in Antarctica.

Stromatoporoids and a number of calcareous sponge groups capable of secreting massive skeletons diversified in the Ordovician. Stromatoporoids are main contributors to patch reefs in Ordovician and Silurian carbonates. Chaetitids, sphinctozoans, and a few other groups are important in Late Paleozoic build-ups. Calcareous sponges are also important in Mesozoic reefs – for example, they were principal builders of the great reef system that spanned most of Europe in the Jurassic – this poriferan reef was larger than the present day Great Barrier Reef. Since the Cretaceous, however, calcareous sponges have played only a limited role in reef construction. At the same time, siliceous sponges, long an important component of shallow marine ecosystems, retreated largely to deeper waters, at least in part due to the scarcity of silica in surface waters following the Cretaceous radiation of diatoms.

Fossil sponges

1. Examine the available specimens of calcareous and siliceous sponges. What design features do they share? Do any exhibit morphologies that might be particularly adapted to high or low energy water conditions?

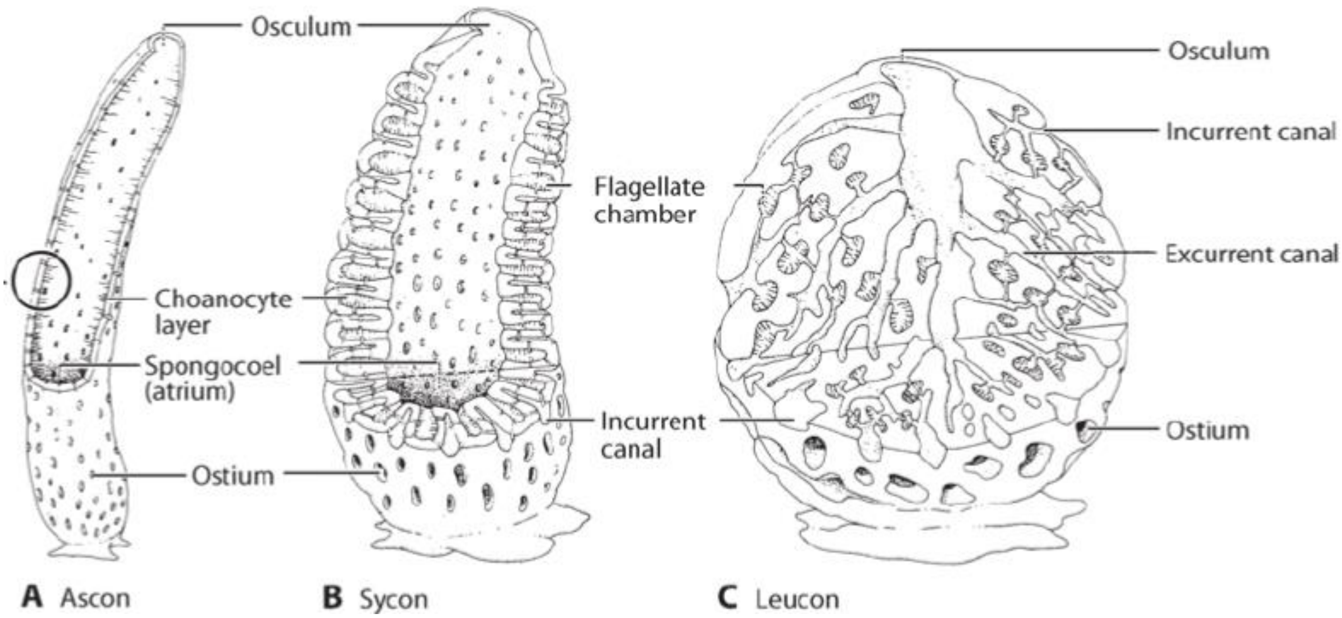


Fig. 1. The three grades of sponges. (A) Ascon, (B) sycon, and (C) leucon, with a detail of a portion of the wall of a typical sponge showing the major morphological features. (Prothero 2013)

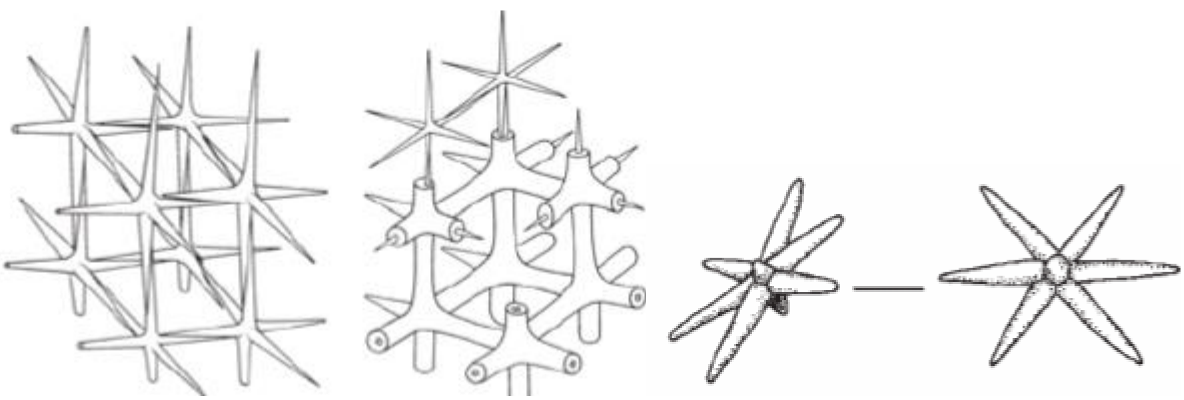


Fig. 2. Examples of sponge spicules (Prothero 2013)

Phylum Cnidaria

The Cnidaria are comprised of some 10,000 living species, nearly all in marine environments. Cnidarians include jellyfish, sea anemones, and corals, among other groups. Despite their variation in morphology, all cnidarians are built on a single anatomical plan: an outer layer of **epidermal tissue** and an inner layer of **digestive tissue** are separated by a non-cellular, commonly gelatinous **mesogloea**. A mouth at the oral end opens into a **gastrovascular cavity**; tentacles surround the mouth opening. All cnidarians contain harpoon-like stinging cells called **nematocysts**.

Polyps are benthic forms, attached to the bottom by a basal disc or differentiated holdfast. **Medusoids** live in the water column, with the mouth and tentacles oriented downward. Polypoid and medusoid forms can exist as alternating generations in a single species. Cnidaria gained complexity by evolving colonial forms in which individuals are specialized for a single function. The Portuguese Man-of-War is one example of a colonial cnidarian; sea pens, octocorals and many true corals are also colonial.

Systematic Biology

Hydrozoa: Commonly small organisms that may display alternation of polypoid and medusoid generations. Some common examples are: *Hydra, Velella* (by-the-wind sailor), *Physalia* (Portuguese man-of-war), hydrocorals, and “fire corals” (*Millepora*).

Scyphozoa: “True jellyfish” – medusoid is conspicuous form. Rarely fossilized.

Anthozoa: Solitary or colonial polypoids – medusoid stage is absent. Gastrovascular cavity dividied up by radially oriented **septa**. Sea anemones, corals, octocorals, gorgonians, sea pens. The **Rugosa** are an extinct Paleozoic groups of corals characterized by calcitic skeletons and tetraradiate symmetry. Modern corals belong to the **Scleractinia**, characterized by aragonitic skeletons and hexaradiate symmetry. The **Tabulata** are a distinctive group of colonial, skeletonized corals that living during the Paleozoic Era.

Geological History

Many Ediacaran taxa have been interpreted as stem- or crown-group Cnidaria. Such interpretations are reasonable, although the precise interpretation of many Ediacaran fossils remains uncertain. Coral-like skeletons appear in the Early Cambrian but are minor constituents of fossil assemblages until the Ordovician, when Rugosa and Tabulata diversified as part of a larger radiation of well-skeletonized invertebrates. Solitary rugosans occurred in both reef and level bottom communities in the Ordovician, but did not become principal reef builders until the mid-Paleozoic, when colonial forms diversified. Tabulates were also important in both level bottom and reef communities of the Paleozoic. The tabulates and rugosans both disappeared during the end-Permian mass extinction.

The Scleractinia represent an independent origin of skeletons in a group of sea anemone-like cnidarians that survived the P-Tr extinction. The oldest scleractinian corals occur in mid-Triassic carbonates, and by the late Triassic scleractinians were at least locally important in reefs. Despite this, our modern view of reefs as the constructions of scleractinian corals applies only to the Cenozoic Era.

In this lab, you will focus on examining specimens of rugose and tabulate corals.

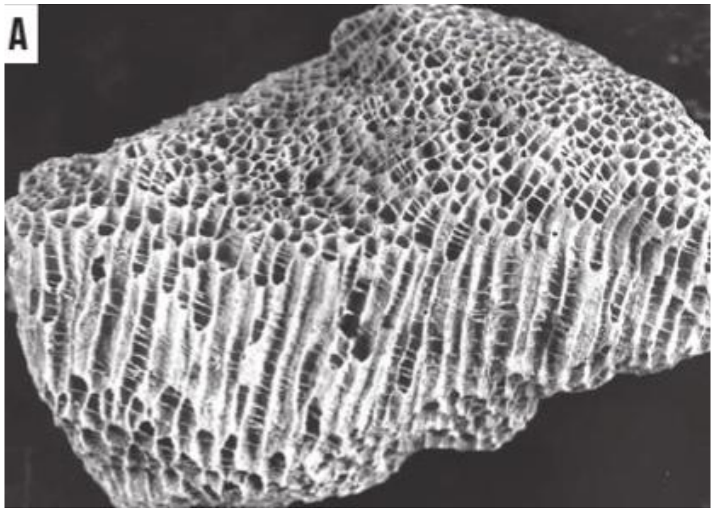


Fig. 3. An example of a tabulate coral. (Prothero 2013)

2. The stony corals are divided into three different orders, two of which were abundant in (and confined to) the Paleozoic: rugosids and tabulates. [The third order, the scleractinians, are exclusively Mesozoic and Cenozoic.] Look at the figures in this lab and the provided specimens; for what features do you think the tabulates and rugosans are named? Make a quick sketch of these two features.

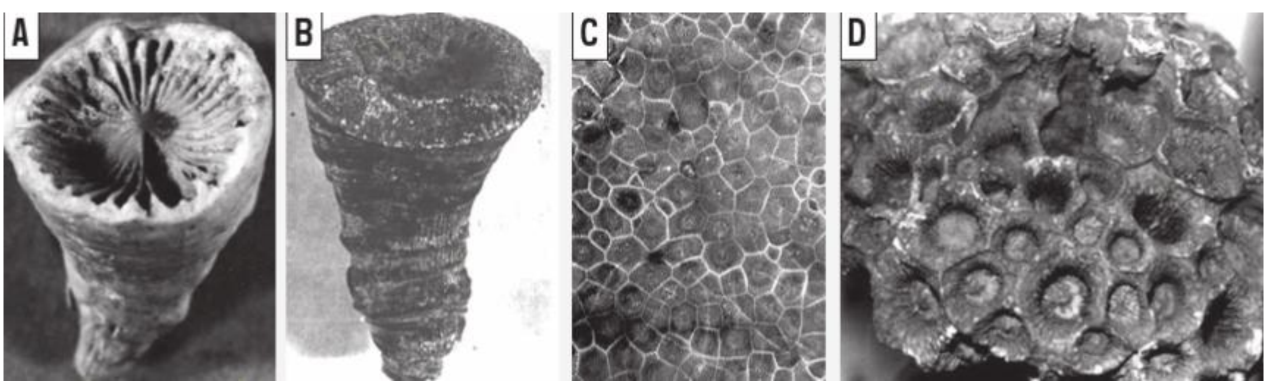


Fig. 4. Examples of rugose corals. A and B are solitary; C and D are colonial. (Prothero 2013)

3. Examine the provided specimens of solitary and colonial rugose corals. What advantages might come from a colonial life style?

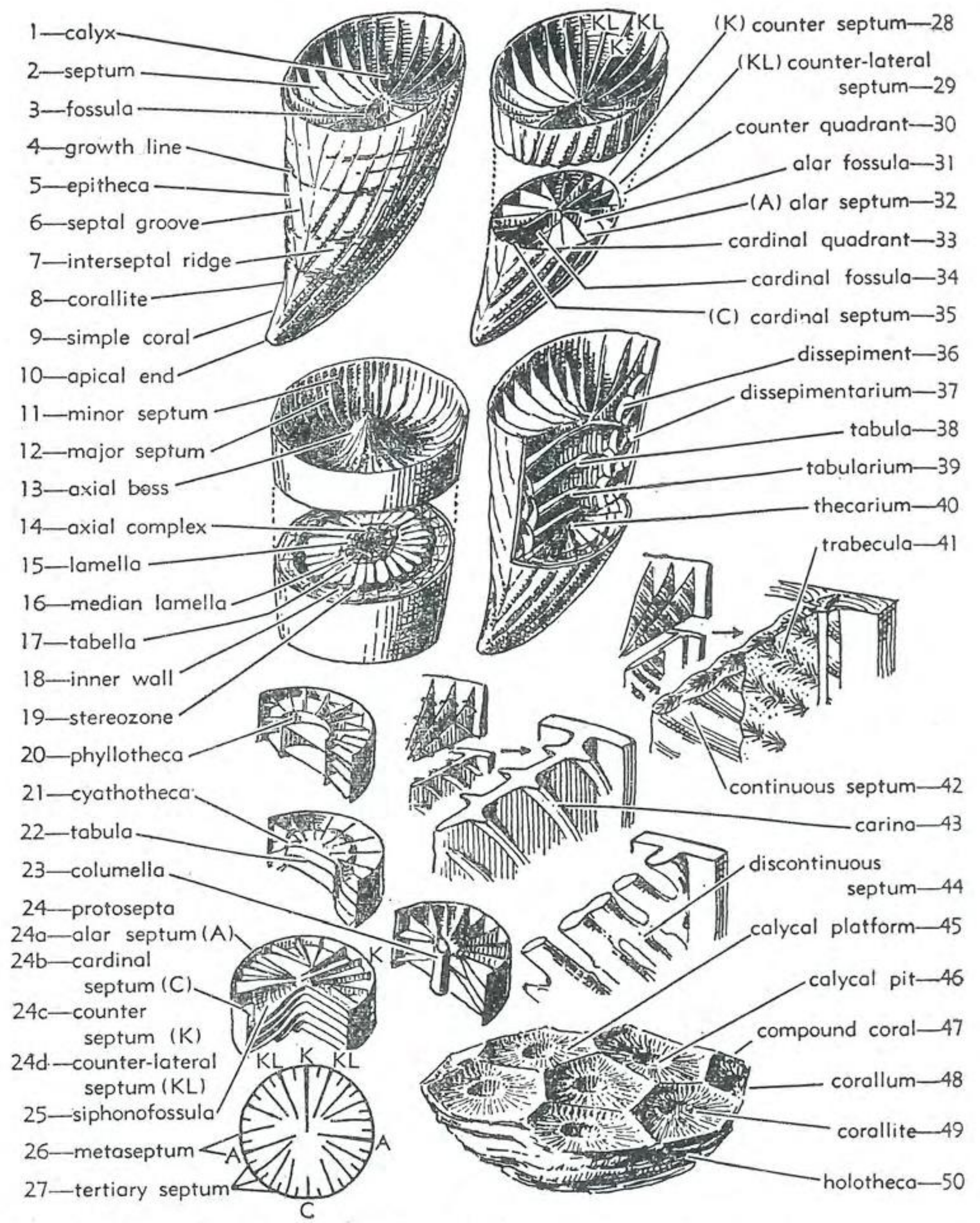


FIG. 4-14. **Morphologic terms commonly applied to rugose corals.** The various terms are explained briefly in the accompanying alphabetically arranged list, cross-indexed to the figure by numbers.

Fig. 5. Labelled diagrams of the exterior and interior of a rugose coral. (Moore et al. 1952)

Some Definitions, with references to Figure 5:

dissepiment (36). Vesicle typically occurring in marginal parts of thecarium, with convexly curved wall toward axis of corallite.

cardinal septum (24b,35). Protoseptum which is adjoined pinnately on both sides by newly inserted septa.

septum (plural septa) (2). Radial wall generally extending from peripheral edge of corallite partly or entirely to its axis, but in some species not extended to the periphery.

fossula (3). Gap or depression in floor of calyx.

4. Examine several specimens of solitary rugose corals to gain some idea of the diversity within this group. Sketch one well-preserved example. Label the following features: **cardinal septum, septa, fossula, dissepiments**. Be sure to include a scale.

5. Observe specimens of the tabulate corals. What features lead us to the conclusion that these skeletons were formed by cnidarians, rather than sponges? Sketch a specimen. Be sure to label the tabulae (and include a scale)!

Phylum Bryozoa

The Bryozoa are lophophorate animals, along with Brachiopods and Phoronids (lophophorate animals with a worm-like morphology). More than 5000 species of bryozoans inhabit the modern oceans, but because most are small, they commonly go unnoticed by casual observers. With few exceptions, bryozoans are colonial. Within colonies, individual sub-mm-scale **zooids** consist of a stationary, more-or-less barrel shaped trunk and an extensible portion that contains the mouth and surrounding lophophore. The trunk secretes a chitinous coating that in many species becomes mineralized by calcite. The calcified cavity containing the soft tissue is generally called the **zooecium** or **autopore**, and the opening through which the lophophore is extended is called the **aperture**; in many marine species the aperture has a lid (the **operculum**). Each zooid has a U-shaped gut in which the anus is located outside the lophophore (hence, the other name for this phylum, the **Ectoprocta**, meaning "outside anus").

Colonies may consist of thread-like erect or creeping stolons, fenestrate fans, branching cylinders, encrustations, or massive mounds. In the geological record, colony form commonly correlates with physical environment, with more massive colonies inhabiting zones of strong or persistent wave activity. Intracolony communication is facilitated by the **funiculus**, a nutrient-conducting cord that connects adjacent zooids. Some zooids may become specialized for colony defense, depending on other individuals for shared nutrients but providing the valuable service of protecting the colony from overgrowth and predators.

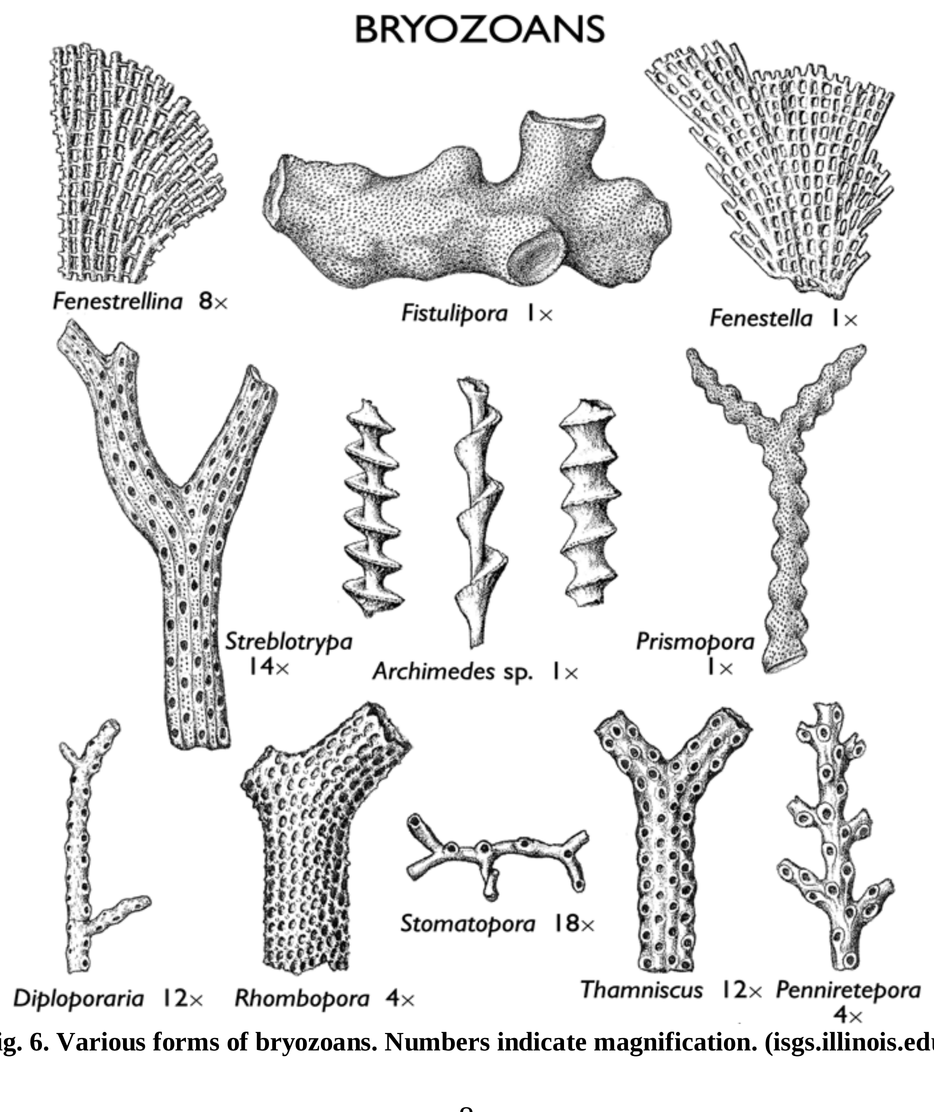


Fig. 6. Various forms of bryozoans. Numbers indicate magnification. (isgs.illinois.edu)

Taxonomy

The Bryozoa are generally divided into three classes. The Class Phytolactolaemata consists of freshwater bryozoans that do not form mineralized exoskeletons; they have essentially no fossil record. Fossil and living marine bryozoans are placed in two classes.

Class **Stenolaemata**: Zooids tubular, with calcified walls that are fused between adjacent zooids. apertures circular and terminal. Lophophore protrusion does not depend on deformation of body wall. Zooid tubes generally partitioned by transverse **diaphragms.** Curved **cystiphragms** may also be present. Clusters of small zooids called **maculae** may form distinct surficial bumps or star-shaped patterns. Early Ordovician-Recent.

Class **Gymnolaemata:** Zooids cylindrical or flattened; Protrusion of lophophore depends on deformation of body wall. Late Ordovician-Recent.

> Order **Ctenostomata**: Stoloniferous or compact colonies, uncalcified walls, terminal aperture without operculum. Found in geological record as netlike external molds, mostly borings in shells. Late Ordovician-Recent.
>
> Order **Cheilostomata**: Calcified gymnolaemates with box-like zooids having walls that abut against but do not fuse with the walls of adjacent zooids. Aperture usually operculate. Late Jurassic-Recent.

Geological History

Most pre-Cretaceous bryozoans are stenolaemates. This class diversified as part of the broader Ordovician radiation of well-calcified sessile marine invertebrates. In Paleozoic carbonates, bryozoans can be dominant contributors to sediment accumulation. Lacy bryozoans can also be abundant in siltstones and shales, especially in Devonian and younger successions. Four of the five principal groups of stenolaemates disappeared during the Permo-Triassic extinction. The remaining group rediversified in the Mesozoic, but from the Cretaceous onward became subordinate to diversifying Cheilostomes.

Pre-Jurassic gymnolaemates are recorded exclusively by the molds of ctenostomes. As noted above, however, cheilostomes evolved during the latest Jurassic and have since become the most abundant and diverse bryozoans. It has been suggested that cheilostome success reflects their superior ability to colonize and encrust substrates. Although Mesozoic and Cenozoic bryozoans seldom match the contribution to carbonate sediments made by their Paleozoic relatives, bryozoans can be major components of carbonate sediments accumulating on cool temperate shelves. Tertiary carbonate shelves along the south coast of Australia are famously rich in bryozoan remains.

6. Bryozoans are also colonial animals. Examine the diameter of an average-sized individual in the provided hand specimen of a tabulate coral colony. Now examine the provided fossil bryozoan (you may need a hand lens). How does the size of individuals compare with coral polyps?

7. Bryozoans are frequently described by their colony shape since it is usually necessary to use microscopes and thin sections for detailed taxonomic identification. **Therefore, it is more useful for the purposes of this lab to think about the relationship between colony morphology and ecology.** Sketch examples of encrusting, ramose (dendritic), and fenestrate bryozoan colonies. What are the encrusting bryozoans encrusting onto?

7.5. What two types of colonies are represented on the small slab provided?

8. Using specimens from Question 7, which forms are likely to occur in high-energy environments? Which forms were likely restricted to low energy environments? Why?

Brachiopods

Along with the bryozoans and phoronids, brachiopods belong to a group called the **lophophorates.** Lophophorate phyla are united by the presence of a **lophophore**, a horseshoe or ring of tentacles around the mouth formed by outpouching of a portion of the **coelom**, or body cavity. The phylogenetic relationships of lophophorates have long been the subject of debate. These invertebrates display developmental traits similar to those of deuterostomes (and some hemichordates have tentacles that closely approximate lophophores). Other features, such as nephridial anatomy, ally them to protostomes. In recent years, molecular sequence data have weighed in strongly in favor of protostome relationships, requiring that the developmental characters shared by lophophorate animals and deuterostomes be interpreted as shared ancestral characters or as convergently evolved features. Today, most biologists accept that the lophophorate phyla are united with phyla that share a trochophore larva (molluscs, annelids, and related groups) to form a large subclade of protostomes christened the **Lophotrochozoa**.

The brachiopods are united by the presence of a **bivalved shell** in which the plane of symmetry runs perpendicular to the **hinge line** rather than along it (as in bivalved molluscs). Viscera are restricted to a small volume near the hinge, while a mantle extends the length of the shell. Most of the volume within the shell is taken up by the lophophore apparatus -- tentacles are arrayed along a support called the **brachium**, which may be simple or complexly coiled. In some groups, the brachia are mineralized and, hence, preserved in fossils. Brachiopods feed by drawing water through shell interior so that it passes through the lophophore, where food particles are filtered out and carried to the gut. Many living brachiopods are attached to the substrate by a cylindrical tether called the **pedicle**, which is an extension of the body cavity. The lingulid clade is unique in having infaunal species. Although many extinct brachiopods were also pediculate, others appear to have lost their pedicle early in development, living untethered on or partially within unconsolidated sediments.

Taxonomy

Traditionally, the brachiopods were divided into two major groups: the Articulata and Inarticulata. In this classification, the Inarticulata are united by the presence of thin, nearly identical valves held together by muscles alone; a flow-through gut; and a hollow, well-muscularized **pedicle**. Most inarticulates have chitinous skeletons impregnated with phosphate, although some groups, including the extant craniids, have calcareous skeletons. As their name implies, the Articulata have calcium carbonate valves that articulate by means of a tooth and socket structure. They have a blind gut (i.e., mouth but no anus!), and the solid pedicle may not contain muscles (and may be absent in adults).

***More recently, traditionally inarticulate brachiopods with calcareous shells (especially the Craniida) have been united with the articulates to form a monophyletic group called the **Calciata** that is sister to the phosphatic inarticulates, or **Lingulata** -- developmental and anatomical features support this rearrangement. It appears that the old Articulata were monophyletic, but the Inarticulata were paraphyletic. The new classification system is preferred because it splits the brachiopods into two monophyletic groups.

Lingulida: Inarticulate brachiopods, characterized by a fingernail shaped phosphatic shell. Includes infaunal species. Early Cambrian to Recent; common in organic-rich mudstones, including those formed in restricted coastal environments. Common examples are: *Lingula, Lingulella, Discinisca*.

*****Craniida**: Small, morphologically simple inarticulate brachiopods with circular outline, calcareous shells. Silica tablets may form on mantle prior to carbonate biomineralization. Cambrian to Recent.

Orthida: Articulate brachiopods with biconvex, unequal valves, a well developed hinge line, and, commonly, ribs; **brachiophores** that supported simple, unmineralized brachia. Early Cambrian-Permian.

Strophomenidina: Articulate brachiopods with a long hinge line, semi-circular outline, well-developed inter-area on both valves. One valve generally concave. Ordovician to Triassic.

Rhynchonellida: Articulate brachiopods. Astrophic (no long hinge line), biconvex, **plicate** (corrugations, or strong ribs extending from umbo to margins, and commissure folded into **fold and sulcus.** Ordovician to Recent.

Spiriferida: Articulate brachiopods. Spiral lophophore supports. May be astrophic (atrypids) or strongly strophic (spiriferids). Ordovician to Jurassic. Especially common in the Devonian.

Pentamerida: Articulate brachiopods. Commonly astrophic and strongly biconvex, with a prominent beak on one valve. Spoon shaped **spondylium** on ventral valve. Cambrian to Devonian.

Terebratulida: Articulate brachiopods. Astrophic, biconvex shells, with distinctive pedicle foramen. Loop support for lophophore. Devonian to Recent.

Geological History. Brachiopods differentiated as part of the Cambrian explosion, and lingulids, craniids, and other inarticulate groups were relatively diverse components of Cambrian faunas. Inarticulate diversity declined after the Cambrian, but articulates radiated dramatically in the Ordovician to become one of the most abundant components of Paleozoic marine faunas. Orthids and strophomenids are particularly abundant in Ordovician and Silurian faunas; pentamerids abound in Silurian and Devonian faunas, while spiriferids are particularly diverse in the Devonian faunas. Late Paleozoic brachiopods are dominated by **productids**, a subclade of the strophomenids.

More than ninety percent of all brachiopod genera disappeared at the end of the Permian. It is commonly stated that brachiopods never rebounded from the Permian-Triassic extinction, but while brachiopods never regained their former diversity, they are, in fact, quite common in Triassic and earlier Jurassic faunas. With the evolution of shell-crushing animals in the later Mesozoic, however, brachiopods receded in importance. Today articulates (predominantly terebratulids) are found mostly in deeper waters and other habitats where predation pressure is low. Inarticulates live mostly in organic-rich, muddy habitats.

Only about 300 species of brachiopods are known in the modern oceans. In contrast, more than 12,000 species have been described as fossils.

9. What morphological structure do brachiopods and bryozoans share that has caused them to be classified as phylogenetically closely related? What is the function of this structure?

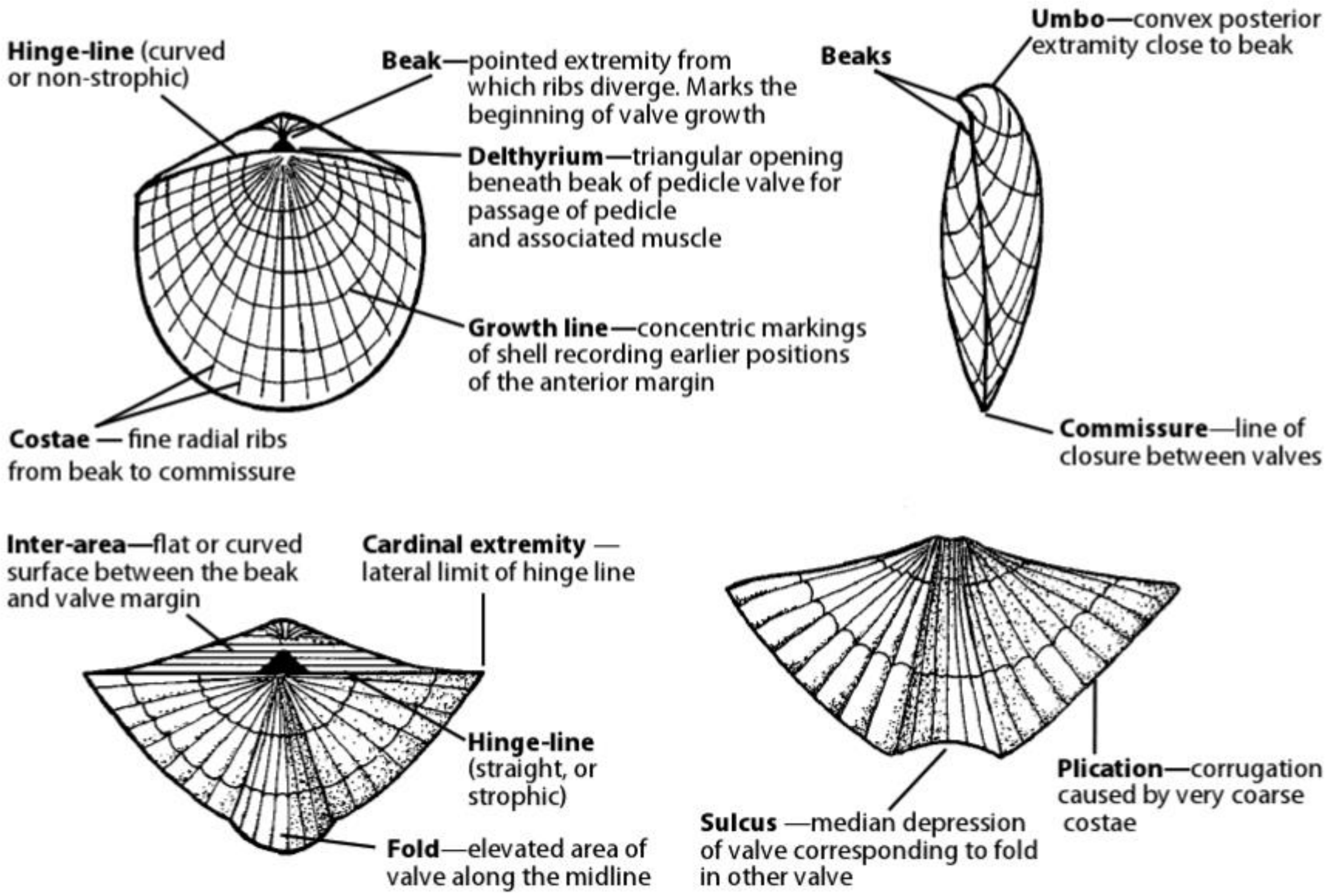


Fig. 7. The external features of brachiopods. (Prothero 2013)

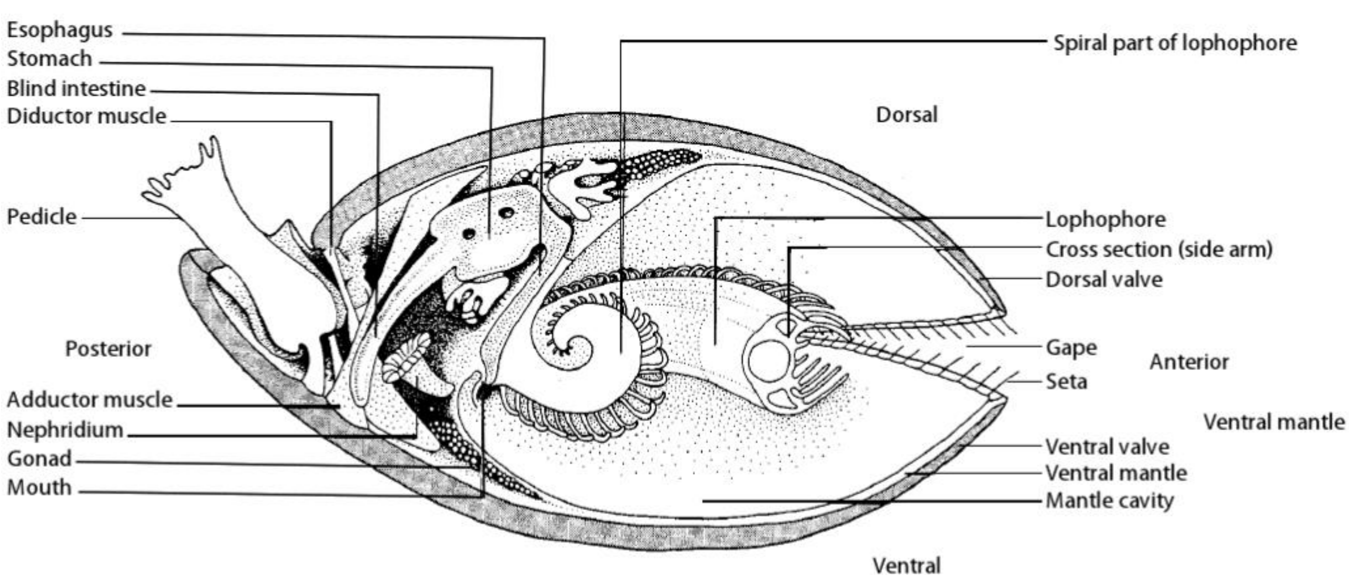


Fig. 8. The internal anatomy of brachiopods. (Prothero 2013)

10. Sketch an example of a lingulid brachiopod. How do they differ from other brachiopods?

11. Sketch two examples of calciate brachiopods – one showing the external shell and one that is cut to see internal structure. Use the diagram above to label the anatomical features – like the **brachidium** in the cut specimens. Find and draw the plane of bilateral symmetry.

12. Examine the silicified brachiopods from the Permian of West Texas. How were these fossils extracted from the limestone matrix? What can we learn from these specimens that might be different from specimens preserved in more conventional ways?

Summary

Describe for the following organisms **1)** their feeding habits (suspension or filter feeders, sediment feeders, herbivores, carnivores/scavengers) **2)** how they move: are they sessile (stationary), planktonic (floating), nektonic (swimming), or motile along the sea bottom? **3)** where they live: are they benthic (seafloor/bottom-dwelling) or pelagic (of the open ocean)?

Sponges –

Corals –

Bryozoans –

Brachiopods –

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