GEOLOGY 217

INVERTEBRATE PALEONTOLOGY LABORATORY

FOSSILIZATION

This collection of lab specimens is representative of the variety of fossilization processes outlined in the lab handout. Examine each of the numbered specimens and answer the following questions as completely as you can.

1. Give a simple identification of the preserved organism(s), organic traces, or fossils made by organisms. Examples of sufficient identification are as follows: clam shells, or brachiopods and bryozoans, or worm trails. If necessary, use a textbook to help you with the identification.

2. What process(es) of preservation is illustrated by the specimen.

3. Briefly state how preservation occurred (use references if needed). Tell what you can about the initial conditions of burial and subsequent changes which took place after burial.

SPECIMEN DATA

	Fossil(s) ID	Preservation Mode	Preservation Scenario
1.			
2.			
3.			
4.			
5.			
6.			

	Fossil(s) ID	Preservation Mode	Preservation Scenario
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			

GEOLOGY 217 – Invertebrate Paleontology

FOSSILIZATION (TAPHONOMY)

I. FOSSIL REMAINS OF ORGANISMS

A. SOFT PARTS (very rarely fossilized)

1. Unaltered: preservation by freezing of mummification.

2. Altered: preservation by petrification of soft tissues; preservation in amber (mainly insects and/or plant fragments) or in peat bogs.

B. HARD PARTS (commonly fossilized)

1. Unaltered: direct preservation of shells and microfossil tests, spicules, bones, teeth, wood, etc. in a sedimentary matrix.

2. Altered: preservation resulting from one or more of the following processes:

a. **Leaching and weathering**: a destructive process that can affect all hard parts.

b. **Carbonization** (distillation): original form preserved only as a thin carbon film; common for graptolites, fishes and plants.

c. **Permineralization** and infiltration: porous hard parts are made more dense by the deposition of mineral substances, usually calcite or silica by ground water (permineralization). Larger voids are commonly infiltrated by the surrounding sedimentary medium, aiding in preservation of the whole fossil. Example--lime mud (micrite) usually infiltrates fossils in a carbonate environment.

d. **Recrystallization**: inversion of unstable aragonite and high magnesium calcite to stable, low magnesium calcite. This is a common process for calcareous hard parts. Microstructure of shell usually not preserved.

e. **Replacement**: original hard part material is replaced by another substance. This process may involve direct substitution of chemical ions (microstructure preserved) or solution and replacement by new compound (microstructure destroyed). Common replacement substances are:

Calcite (calcification)
Dolomite (dolomitization)
Glauconite (glauconitization)
Hematite (hematization)
Pyrite (pyritization)
Silica (silicification)

NOTE:

Permineralization and infiltration, recrystallization and replacement are the most common modes of fossil preservation. These processes commonly combine to achieve final preservation.

II. MOLDS AND CASTS

A. SOFT PARTS (very rarely fossilized)

Preservation consists of molded imprints on bedding planes in fine-grained clastic rocks (shales and sandstones) and micritic limestones.

B. HARD PARTS (commonly fossilized)

1. External molds and internal molds (= steinkerns) are formed by solution of original material after or during lithification of sedimentary matrix, leaving an imprint of the exterior or interior surface of the shell or other hard part. Brachiopods and mollusks commonly are preserved in this manner.

2. Casts are formed by the filling and hardening of matrix in an external or internal mold (rare relative to the formation of molds).

III. TRACE FOSSILS

A. Tracks and trails.
B. Burrows, preserved in full relief or as casts.
C. Borings.
D. Coprolites (fossil excrement), preserved by a variety of replacement processes or as molds.
E. Gastroliths (gizzard stones) found in association with dinosaur fossils; occur as polished stones.

IV. PSEUDOFOSSILS

Pseudofossils are objects that may resemble fossils but originate without organic influence. Such objects include concretions, dendrites, certain physical sedimentary structures, weathering phenomena etc.

Reference:

Muller, A. H. 1979. Fossilization pp. A2-A87 in Treatise on Invertebrate Paleontology.

THE FATE OF SKELTAL MATERIALS, POSSIBLE PATHWAYS

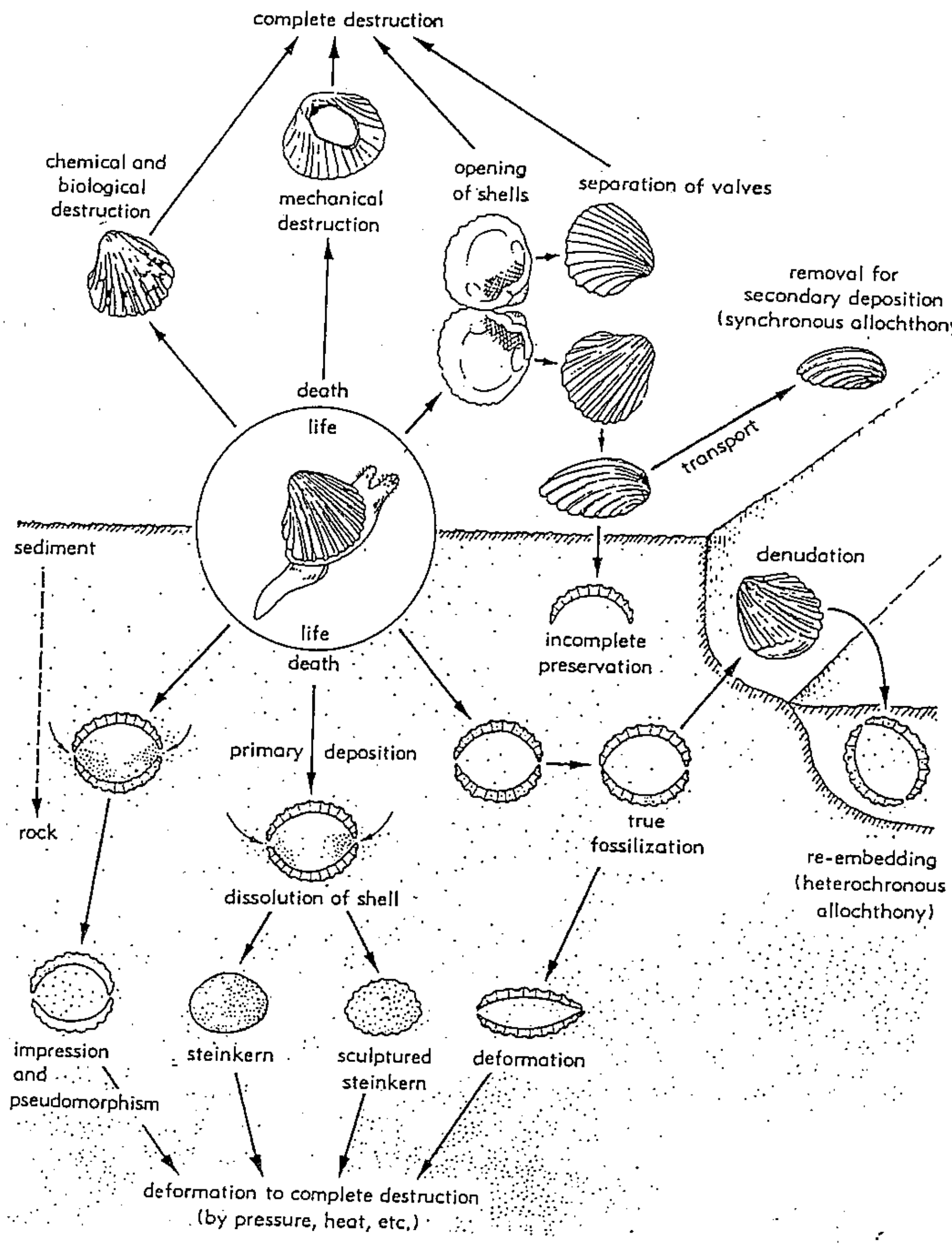

FIG. 1. Diagrammatic representation of fate of skeletal material after the death of the animal (after Thenius, 1963).

from the Treatise, Vol. A, p. A4.

SUMMARY OF TAPHONOMIC INDICATORS AND THEIR PALEOENVIRONMENTAL IMPLICATIONS

* * * * * *

Taphonomic Feature	Implications
Abrasion	The wearing-down of skeletons owing to differential movement with respect to sediments is an indicator of environmental energy. Significant abrasion is most commonly found on skeletal material collected from beaches, or areas of strong currents or wave action.
Articulation	Multi-element skeletons are soon disarticulated after death. Articulated skeletons, then, indicate rapid burial or otherwise removing the skeleton from the effects of energy of the original environment.
Bioerosion	Bioerosion encompasses the many different corrasive processes by organisms. The most pervasive causes of degradation are boring and grazing. Bioerosion erases information from the fossil record, but it also leaves identifiable traces made by organisms on remaining hard skeletons or surfaces. Therefore, trace fossils produced by bioerosion add information on the diversity of ancient assemblages.
Dissolution	Skeletal remains commonly are in equilibrium with surrounding waters, but changes in chemical conditions can cause skeletons to dissolve. Dissolution represents fluctuation in temperature, pH or pCO_2 in calcium carbonate skeletons. Silicious skeletons also can dissolve because normal sea water is usually undersaturated with respect to silica.
Edge rounding	Broken edges of skeletons become rounded owing to dissolution and/or abrasion of exposed surfaces. Processes that control edge rounding probably include a combination of dissolution, abrasion, and bioerosion. Rounding gives an estimate of time since breakage.
Encrustation	The growth of hard skeleton substrates by other organisms is a common occurrence. Besides indicating exposure of the skeleton above the sediment-water interface, encrustation can specify a particular environment. Different patterns of encrustation, as well as different biota, occur in different environments.

Fragmentation Breakage of skeletons is usually an indication of high energy resulting from wave action or current energy. Fragmentation also can be caused by other organisms through either predation or scavenging.

Orientation After death, skeletal remains are moved by the transporting medium and oriented relative to their hydrodynamic properties. Fossil skeletons in life position indicate rapid burial, attachment to a firm substrate, or death of in-place infauna. Hard parts tend to orient long-axis parallel to unidirectional flow in current-dominated areas and perpendicular to wave crests on wave-dominated bottoms.

Size After death and if not rapidly buried, a skeleton behaves as a sedimentary particle and is moved and sorted with respect to the carrying capacity of the flow of currents, waves, or tides. Size can, therefore, be an effective indicator of flow capacity in a hydraulic or wind-driven system.

Modified from Parsons, K.M. and Brett, C.E., 1991, Taphonomic processes and biases in modern marine environments, in Donovan, S.K., *The Processes of Fossilization*: Columbia University Press, New York, p. 22-65.

GEOLOGY 217: PALEONTOLOGY
TRACE FOSSILS

Trace fossils or ichnofossils represent the effects of organismal activity upon or in the substrate. Tracks, trails, borings etc. are the most commonly encountered traces. Fossilized fecal material (coprolites) may also be referred to as trace fossils due to the obvious indication of organism activity without the presence of actual "body fossils". In this manner, a distinction may be made between body fossils, which are actual remains of the organism, and trace fossils which represent a representation of an organism's behavioral activity.

You should be aware of the following terms:

ichnofossil
protrusive spreite
retrusive spreite
pascichnia
cubichnia
coprolite
toponomic classification
endichnia, hypichnia, exichnia, epichnia
ichnology
repichnia
fodinichnia
domichnia
fugichnia
ethological classification

1. Repichnia, ichnogenus unknown. This is a "worm" burrow exhibiting traces of movement through the sediment. Examine the prominent fossils on the slab carefully and present an analysis of where and how the organism lived relative to the sediment substrate. What do the transverse ridges represent? What can you conclude about the body organization of the animal? In which ichnofacies would you place this form?

2. *Ophiomorpha* -- burrows are common in intertidal and shallow subtidal environments. What ethologic term applies to these?

3. *Crossiopoda*-- What do these structures represent and to which behavioral (ethologic) category do they belong?

4. *Cruziana* – What can you conclude about the body organization of the animal that made this trace? Why? What descriptive terms (ethological and positional) would you apply to this ichnotype?

5. *Asteriacites* -- this is a hiding trace of a starfish. What ethologic and toponomic classification would you give these? The scratch marks on the largest specimen were made by the starfish's tube feet. Is any additional paleocecological information preserved on this rock? If so, what type evidence is present?

6. Gyrolithes – the "devil's corkscrew". This is a burrow of a terrestrial rodent. What ethological classification would this be given?

7. This is *Zoophycus*. What ethological category would this trace fossil be placed into? Why? Draw a schematic diagram to illustrate the processes giving rise to the format of this trace. In which ichnofacies would you place this form?

8. "Arnhein-Rumpke" slab – What specific cubichnia are represented here? If these are resting traces, why aren't the trails leading into or out of them preserved?

9. Gastroliths – These are dinosaur gizzard stones, polished in the process of grinding food. Gastroliths are often found among dinosaur and bird remains, somewhat like a "winnowed lag" deposit.

10. Coprolites – Fossilized dung. A great deal of information can be gleaned from these trace fossils, including soft part anatomy and dietary habits. In fact, a scientific organization with the acronym C. R. A. P. (Coprolite Research Association of Paleontologists) exists to further knowledge on this topic. Wash hands after examination.

11. These bore holes are made by a clam (bivalve) belonging to a group known as the lithophagids (literally, stone eater). Some of the clams are still visible in the bore holes. These organisms are common today and their larvae settle on hard substrates and bore inside them. As the clam grows, it increases the size of its burrow, spending its entire life within the hard substrate (either rock or reef framework). What are the advantages and disadvantages to this life style? What are the taphonomic consequences of bioerosion?

GEO 217 – INVERTEBRATE PALEONTOLOGY
PROTISTS AND MICROPALEONTOLOGICAL TECHNIQUES

Microfossils are particularly valuable index fossils because their small size allows them to be recovered in large numbers from grab samples taken from the ocean floor or from subsurface cores. Planktic microfossils normally have wide geographic distribution in contemporaneous marine sediments. The incorporation of stable isotopes of oxygen within the calcite shells of many microfossils (particularly foraminifera) makes them essential tools for the reconstruction of paleoclimate. Since many of the planktic groups also evolved rapidly over geologic time, these microfossils are exceptionally useful as time indicators. Benthic microfossils normally are more restricted in geographic distribution, owing to the great variety of bottom environments and the more restrictive ecologic conditions that exist there. For these reasons benthic microfossils are most useful in the interpretation of marine paleoenvironments and paleoecology. Specifically, the ratio of planktic to benthic foraminifera in a sample is a fairly reliable indicator of water depth.

PART I. ANALYSIS OF PLANKTIC AND BENTHIC FORAMINIFERA

You will receive a "mystery" sediment sample of Holocene age that contains foraminifera (affectionately known as forams). I will reveal the location at a later date; you will determine depth and environment.

Analysis of the sample will proceed as follows:

A. Isolation of forams from the sample:

1. Weigh the sample on the balance, record weight on a data sheet.
2. Wash the sample through #60, #120, and #230 standard sieves in the lab sink. Foram-bearing sediment will be retained on the #120 and #230 screens. Some large forams may be on the # 60 screen.
3. Transfer washed samples to filter paper by washing the samples through a funnel lined with filter paper. Place the wet sample and filter paper in the drying oven. Be sure that filter papers are labeled with sample numbers and your name.
4. After complete drying, gently transfer each foram sample to a small vial. The samples now are ready for final weighing and for foram picking. Be sure each vial is labeled with a slip of paper placed inside the vial.

B. Foram picking:

Use the micro-splitter to reduce your #60 sample size to approximately 300-500 grains (retain the rest of the sample). Evenly sprinkle the grains you have isolated onto a picking tray. Examine the sample under a microscope, and discriminate forams from other grains. Your micropaleo slide has been prepared with water-soluble glue. You can mount forams by dipping your brush in water, picking up a foram and putting it on the slide. You can move specimens about after initial mounting simply by applying a wetted brush to them..

C. Planktic and benthic foram percentages:

Using the available references and information from me, determine which of your specimens were planktic and which were benthic. Segregate the planktic specimens and determine the percentage of planktic specimens in the sample.

D. Benthic foram wall structure:

Divide the benthic specimens into three groups according to wall structure characteristics. It is possible that all three wall types won't be represented.

a. Agglutinated tests
b. Calcareous porcelanous (imperforate) tests
c. Calcareous hyaline tests

E. Identification:

Use the available literature to identify some specimens to generic and specific level. Mount specimens representing four planktic species and 4 benthic genera. Isolate the identified specimens into separate boxes on the faunal slide. You will use the numbers to key your identified forams in your report. You may also mount any other grains that are of interest to you

F. Summary report:

Your findings will be summarized in a short report. Guidelines for this report are attached.

SEDIMENT ANALYSIS DATA SHEET

Sample ____________

Dry wgt. ___________g

#60 wgt. ___________g; _____________%

#120 wgt. __________g; _____________%

#230 wgt. __________g; _____________%

silt & clay wgt. ________g; ______________%

Total________________%

Description of sand mineralogy:

FORMAT FOR FINAL REPORT

A short report of the findings of your foraminiferal sample analysis will be due on the date indicated on the syllabus. There is no need for this to be a lengthy document, but should definitely be written as and be in the format of a report, not just a collection of observations. Your report should contain the following sections:

1. Introduction—make a brief statement of the nature of the problem. Give age of the sample.

2. Sample description—give a brief description of each sample in terms of its sedimentary characteristics (i.e., sediment texture, mineralogic composition, grain shapes etc.). Attach the sediment analysis data sheet and histogram (use any graphical software you are familiar with to generate the histogram – see me if you have not yet learned how to produce graphs on a computer) here and integrate your findings regarding the characteristics of the sediments into this short written description of the sample.

3. Foraminiferal identifications—each investigator is responsible for the identification of 4 planktic forams to the **SPECIES** level and 4 benthic forams to the **GENUS** level. The identified specimens should be mounted on a micropaleo slide with the box numbers keyed to the names given in this section of the report. For each identified taxon, give a capsule description of the taxon to include the definitive characteristics of the genus or species. DON'T simply copy the descriptions from the relevant literature. Instead identify which features you used to make the identification. Feel free to use the frame-grabbing software on the lab computer to include a photo of each specimen next to its description.

4. Environment of deposition—for each sample, make a short statement of your interpretation of the probable environment of deposition (including water depth). Give as much supporting evidence as you can. The planktic/benthic percentages for each sample should be presented here. These data should be helpful in determining the water depth of deposition for the sample.

PART II. PROTOCTIST STUDY SET

Protoctists

The proctoctists include the eukaryotic microorganisms: nucleated algae (greens, reds, browns - seaweeds), water molds, slime molds and slime nets and, of particular interest to paleontologists, the protozoans. New developments in molecular biology have placed the higher-level classification of these organisms in a state of flux; the system of five "kingdoms of life" is being replaced. Regardless, there are 27 major groups assigned to this group, and we will study only those of direct interest to paleontology. The groups are not always considered as phyla, but are treated as classes or orders by some workers, depending on the classification used.

I. Phylum Chlorophyta (green algae)

This phylum comprises the largest group of algae, the green algae, common in both marine and fresh water. The plant body may consist of a single cell, a colony, a filament or a plate of cells. Range: Precambrian? - Recent.

Within two families of the chlorophytes calcareous secretion occurs, whereby calcium carbonate is impregnated within the outer layer of the cell wall. Green algae, along with calcareous red and brown algae, are major producers of calcium carbonate sediments and also aid in the binding and trapping of sediment.

Family Dasycladaceae: *Acetabularia* no specimen available

A. Family Codiaceae: Halimeda, Udotea, Penicillus, Rhiphocephalus
B. Receptaculites: these Paleozoic fossils have long been a taxonomic enigma, variously classified as algae, sponges or corals. Their most recent classification allies them with green algae.

II. Phylum Rhodophyta (red algae)

Red algae are almost exclusively marine and best developed in warm seas. Coralline or crustose red algae secrete $CaCO_3$ in their "tissue" and resemble corals. The vegetative body is delicate, filamentous and much branched. *Goniolithon* is well known from modern and ancient reefs respectively. Range: Cambrian-Recent.

III. Phylum Protozoa

Many workers have placed all animal-like eukaryotes into a distinct phylum (Protozoa) see Margulis and Schwartz (1982) for an alternative interpretation.

A. Order Foraminifera

The foram test is chambered, often coiled, and usually calcareous in composition and thus highly preservable. Forams are primarily marine, only a few occurring in fresh water. Most are benthic, occurring in all known depths. A small number are planktic. Benthic forms may be free-living, or attached permanently (e.g. *Homotrema*) or semipermanently to seaweeds or shelled material. Chamber form and arrangement is highly variable in forams (see Moore, Lallicker and Fisher, pp. 42-43).

STUDY SET:

1) Examine specimens of *Nummulites laevigatus* under the microscope to observe the internal structure. Representatives of the genus *Nummulites* are among the largest forams known and they can be a major component in rock. The limestones that were used to build the pyramids in Egypt are composed largely of *Nummulites*. These are sagittal sections. Sketch a specimen and label the following structures: proloculus, septa, and chamber (see Boardman, et al., p. 86 for help).
2) Examine the slide of foram-rich sediment from about 1400' of water in the Florida Strait. Most of the forams are planktic species belonging to the genera *Globigerina, Globigerinoides, Globoratella and Orbulina* (see Postuma). Also present are some agglutinated forams (benthic) and fragments of planktic gastropod shells (pteropods) that have a thin, cone-shaped form. Sketch a globular foram.
3) Examine the Pennsylvanian fusulinid limestone slab, then look at the slides of *Triticites* under the micriscope. Fusulinids are excellent index fossils for the Pennsylvanian.

B) Class Actinopoda (radiolarians) - slender, ray-like pseudopods.

Radiolarians, another group secreting siliceous tests, have roughly spherical cells with threadlike pseudopodia extending radially from an endoskeleton. An outer skeleton, also co mmonly present, is composed of loose spicules, external spines, and a porous lattice shell. The tests vary in morphology and are composed of either opaline silica (SiO_2-H_2O), or less commonly strontium sulfate (celestite: $SrSO_4$). The radiolarians are planktic protozoans and are common in deep-sea sediment samples, particularly below the CCD. Range: Cambrian - Recent.

Examine the radiolarian strew slide for familiarization. Much of the delicate ornament is lost when radiolarians are preserved, making them look like rather indistinct blebs of silica.

IV. Although no specimens are available, you should be aware that two additional protoctist phyla are important in the fossil record.

"Phylum" Chrysophyta (yellow green - golden brown algae)

This group is now divided into several distinct phyla and includes two important types of phytoplankton, essential organisms in the marine food chain. **DIATOMS** that secrete a two-part skeleton of opaline silica, and **COCCOLITHOPHORIDS** that secrete calcareous discs, rings or plates (coccoliths) up to a few microns in diameter. Post-mortem disaggregation scatters the coccoliths before or after they have settled to the sea floor where they form a major constituent of calcareous deep sea oozes. Range: Paleozoic? Triassic - Recent.

Phylum Pyrrophyta (fire algae)

This group includes the **DINOFLAGELLATES**, unicellular organisms characterized by a multi-plated test and the possession of two locomotory flagella. Blooms of these organisms form the so-called **red tides** that can affect extensive clam populations. **Zooxanthellae, important symbionts to some corals and foraminifera** also belong to this group. Range: Silurian - Recent.

PLANKTIC FORAM IDENTIFICATION KEY

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This key will be of use to you in identifying the common genera of planktic foraminifera in your deep-sea sample. All identifications should be checked in Postuma's Manual of Planktonic Foraminifera (large blue book in lab), Oligocene-Quaternary section, p. 252-389.

I. Single visible chamber, spherical shape ... ... *ORBULINA universa*

II. Multiple Chambers

A. Chambers subspherical

1. Planispiral coil ... ... *HASTIGERINA*

2. Trochospiral coil

a. Large aperture, shared by chambers of final whorl and opening into umbilicus ... ... *GLOBIGERINA*

b. Similar overall shape as Globigerina but with multiple apertures visible on the spiral side ... ... *GLOBIGERINOIDES*

c. Heavy test wall with "polished" appearance, single large slit-shaped aperture on final chamber only ... ... *PULLENIATINA*

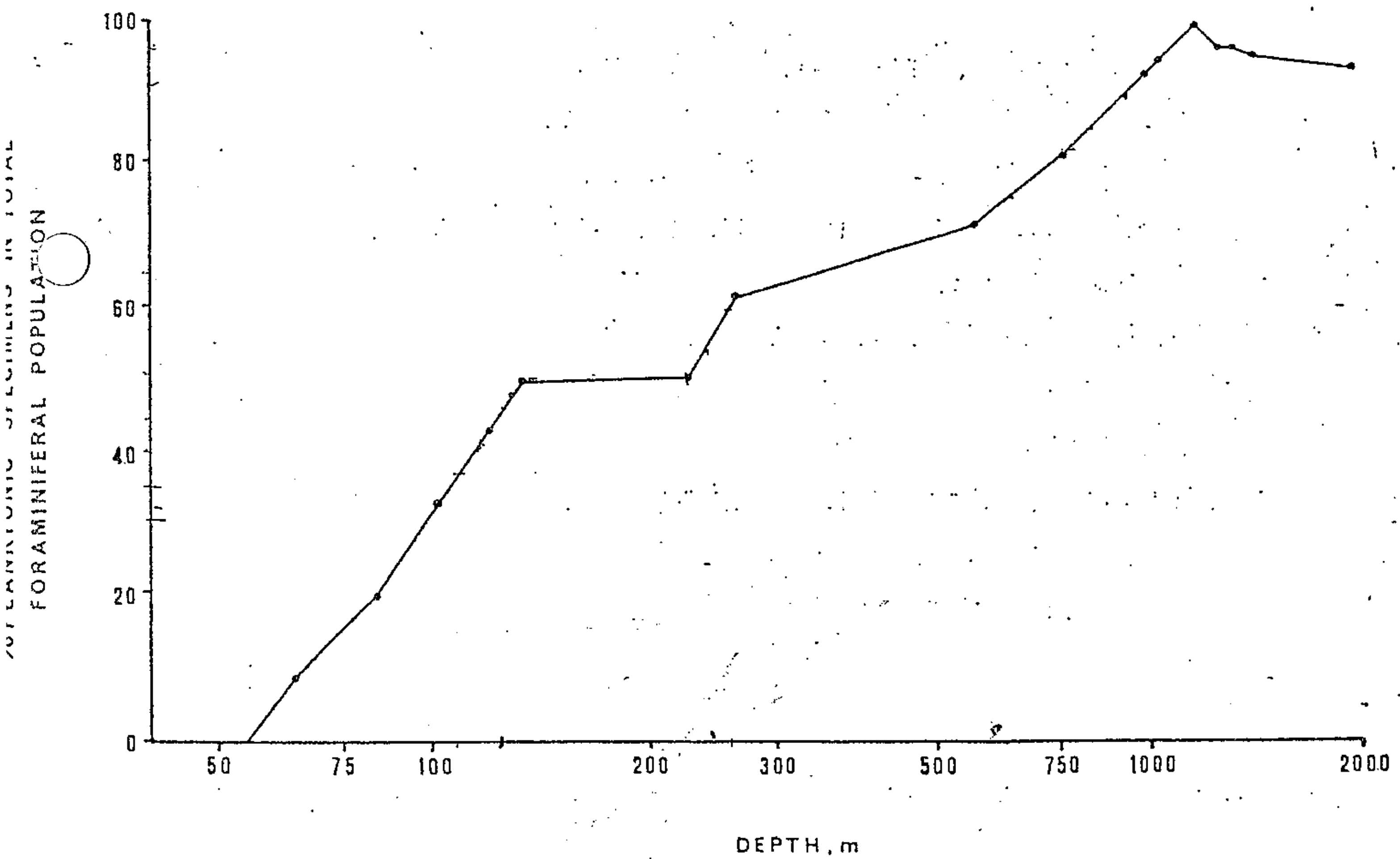
d. Heavy test wall, slit-shaped aperture shared by several chambers around the test "equator" ... ... *SPHAEROIDINELLA*

B. Chambers flattened to somewhat triangular ... ... *GLOBORATALIA*

1. Large, flattened chambers ... ...*G. menardii*

2. Test with a pyramid shape, i.e., one side flattened, one side sharple convex ... ...*G. truncatulinoides*

PLANKTIC/BENTHIC FORAM BATHYMETRY CURVE



. Change in the relative proportion of planktonic and benthonic foraminifera
epth, Gulf of Mexico (after Grimsdale & Morkhoven, 1955).

FROM BOLTOVSKOY & WRIGHT 1976

GEOLOGY 217: SPONGES

Phylum Porifera

You should be familiar with the following terms:

spongocoel
osculum (oscula)
ostium (ostia)
flagellated chamber
choanocyte
pinacocyte
amoebocyte
porocyte
sclerocyte

asconoid
syconoid
leuconoid
spicule

The Phylum Porifera, commonly called sponges, consists of simple multicellular animals living attached to the substratum primarily in marine environments. Because sponges lack differentiated tissues, their level of cellular organization is regarded as intermediate between unicellular forms and true metazoans. A typical sponge (see class handout) has a central cavity (SPONGOCOEL) with a chimney-like opening called the OSCULUM. The body wall is perforated by numerous pores (OSTIA) through which the water enters the incurrent canals and FLAGELLATED CHAMBERS. Microscopic food particles are removed from the water as it passes through the flagellated chambers, and the filtered water then leaves the sponge via excurrent canals and the osculum. The rigidity of the sponge is maintained by the fibrous organic network of SPONGIN which may or may not contain spicules of $CaCO_3$ or SiO_2.

Although sponges lack well-defined tissues, they do possess several types of specialized cells that perform particular functions. CHOANOCYTES, or collar cells, are the most important type. The whip-like flagellum is surrounded by a collar of microvilli (see Boardman et al., p. 117). The feeding current of the sponge is created by the beating of the flagellum. Food particles are trapped by the microvilli and ingested by the cell body. Particles are also engulfed by the AMOEBOCYTES (the chapter in Boardman et al. refers to these as ARCHEAOCYTES) which migrate through the body wall transporting nutrients and also serving reproductive functions. The POROCYTES form the actual incurrent pores or ostia, and the PINACOCYTES control the opening and closing of the pores.

Sponges exhibit three grades of organization or complexity of structure (see class handout). The simplest grade (ASCONOID or ASCON) appears as a single sac-like chamber lined with choanocytes. In a more complex grade (SYCONOID or SYCON), the body wall is folded so that the choanocytes on the interior are restricted to chambers. In the most complex grade (LEUCONOID or LEUCON), the choanocyte chambers are further restricted and are served by incurrent and excurrent canals. The majority of marine sponges are of the leuconoid type.

Because most sponges possess only an organic skeleton of spongin fibers in which spicules are loosely held, entire sponges are rarely preserved in the fossil record. After the death of the sponge, the organic skeleton decays and the spicules are released to become incorporated into the sediment. Thus spicules can occur as microfossils, but can also be concentrated in layers, sometimes forming cherts. Spicules are either calcareous or siliceous, and a sponge secretes only one chemical composition. Spicular mineralogy forms the basis for classification of sponges at the class level. Spicule shapes are highly varied and are often characteristic of the sponge species (see Boardman et al., pp. 121-122). Therefore, sponge taxonomy relies heavily on spicule morphology. Some sponges have rigidly interlocked of fused spicular skeletons, making them more likely candidates for fossilization.

There are four classes of sponges. Listed below are the major characteristics of each class along with notes and questions on the specimens available for examination.

Class Calcarea

Sponges with a skeleton formed of spicules of $CaCO_3$ laid down in the form of calcite. Range: Cambrian - Recent.

1. Sketch *Astraeospongium* , and be sure to include the spicule forms in your sketch. Do you think this was a fused skeleton? Why or why not?

Class Hexactinella

A class of exclusively marine sponges with a skeleton made up basically of siliceous spicules, occurring individually or fused together by supplementary secretions of silica. Range: Cambrian - Recent.

2. *Euplectella* - PLEASE BE VERY CAREFUL WITH THIS SPECIMEN!! Called the "glass sponge" this is a Recent sponge having a rigid skeleton of interwoven fibrous siliceous spicules. Examine under the microscope. The excurrent canal is covered by a sieve plate, and a tuft of siliceous fibers serves to anchor the living sponge to the substrate. This is a deep water sponge: living at depths of 1,500 to 15,000 feet in the western Pacific. Inside the sponge are the remains of at least one shrimp. Commonly a pair of shrimps, male and female, are found within the closed cylinder of the living sponge. This commensal relationship begins when the small shrimps enter the cylinder. They then increase in size and are trapped by the sieve plate. Do you think the name glass sponge is appropriate for these animals? Why? These sponges are almost never found in shallow water. Can you explain why?

3. *Hydnoceras*- this is a common component of Devonian reef systems. Compare this specimen with Euplectella. Note this is an internal mold that preserves the fused spicular skeleton.

Class Demospongiae

Sponges with one- to four-rayed siliceous spicules accompanied in general with varying amounts of spongin and sometimes spongin alone. Fine collagen (a protein) fibrils occur in all demosponges including those that lack both spicules and spongin fibers. Occurring in the sea from the intertidal zone down to at least 7,000 m. Three families of the class are found in fresh water. Range: Cambrian - Recent.

4. Two relatively intact, dried demosponges (Recent). Note the variety of growth forms. Sponges are extremely "plastic" in growth form and are subject to much individual variation in response to environmental variation. The external form within one species can be so variable that form cannot be used as a reliable taxonomic trait. This environmentally-induced variation within a species is called ECOPHENOTYPIC VARIATION.

5. Examine *Calycocoelia* and *Astylospongia.* These are common Paleozoic demosponges.

Class Sclerospongiae

A class of marine sponges with a skeleton composed of siliceous spicules and spongin fibers as well as a basal massive skeleton of calcium carbonate occurring as aragonite or calcite. The Recent members of this group are few in number but are relict species of groups that were common in Mesozoic and Paleozoic eras. Range: Ordovician - Recent.

6. ORDER STROMATOPOROIDA. Examine the specimens with unaided eye and using the microscope (low power). "Stromes" are sponges with a skeleton consisting of transverse elements, called LAMELLAE and vertical elements, called PILLARS. The surface is smooth or raised in eminences, called MAMELONS (not present on all of our specimens), and often (but not on these!) bears radiating depressions in the surface (ASTRORHIZAE) that represent the stellate pattern of the exhalent (excurrent) canals leading to a central osculum). Most fossil specimens are calcitic but it is probable that the original form of the calcium carbonate was aragonite. Some workers regard stromatoporoids as a separate subphylum of sponges, while others regard the group as a fifth class. Recent work has places stromatoporoids in the relatively new class Sclerospongiae. Under this classification, the Recent sclerosponge *Ceratoporella* represents an extant relative of a group that included important reef builders during Paleozoic time. Sketch the specimens of *Actinostroma* and label lamellae, pillars. What distinguishes algal stromatolites from stromatoporoids?

GEOLOGY 217: CNIDARIA (COELENTERATA)

Use available references and specimens. You should be familiar with the basic classification scheme for the cnidarians, and you should be familiar with the well-known rugose and tabulate coral index fossils. Be familiar with the following terms:

Soft part features: polyp
- medusa (-ae)
- tentacles
- nematocyst
- cnidoblast
- coelenteron
- epidermis
- hermatypic
- ahermatypic
- zooxanthellae
- mesoglea
- mesentary (-ies)

Hard part features:
- corallum
- compound
- solitary
- corallite
- calice
- epitheca
- septum (septae)
- tabula (-ae)
- mural pores

The Phylum Cnidaria ranges from the late Precambrian to the Recent. Some workers regard the phylum as the Coelenterata and divide it into two subphyla, the Cnidaria (corals, anemones and hydrozoans) and the Ctenophora (comb jellies). We will be concerned with the Cnidarians. All cnidarians are radially to biradially symmetrical metazoans. They show tissue-grade organization in which there are two cellular layers in the body wall (diploblastic): the outer EPIDERMIS and inner GASTRODERMIS (see class handout). Between these layers is the noncellular, jelly-like layer called the mesoglea. Cnidarians have no definite organs. The body has a central cavity called the COELENTERON or gastrovascular cavity. Its single opening is the mouth which is surrounded by a ring of tentacles. The epidermis of cnidarians (but not ctenophores) contains specialized cells called CNIDOBLASTS (see class handout). These are concentrated particularly in the tentacles. Within each cnidoblast is a tiny capsule called a NEMATOCYST which can forcibly eject a harpoon-like thread when tactiley stimulated. This thread can pierce prey or attacking organisms and inject a toxin. The cnidoblasts and their nematocysts are commonly called stinging cells, and are the most characteristic feature of the cnidarians. There are two body forms in cnidarians, the sessile POLYP and the pelagic MEDUSA or jellyfish (see class handout). Most cnidarians pass through both polyp and medusa stages during their life cycle are thus termed POLYMORPHIC. Polyps can be solitary, compound (grouped) or colonial (multiple polyps having an interconnecting body wall). The three cnidarian classes are distinguished mainly by the relative emphasis on the polyp or medusa during the life cycle. Compare and contrast the characteristics of the three classes as shown in the class handouts.

CLASS HYDROZOA (Cambrian - Recent)

ORDER MILLEPORINA (K-R) "Fire corals" although not closely related to true reef corals (scleractinians). Different growth forms can range from encrusting to platy to branching. Great variability can occur within a single colony or within a species living under different conditions. Milleporids differ from true corals by lacking septa within the pores. They thrive in the surf zone of coral reef crests where they are major framework builders and cementers of other reef constituents. The nematocysts produce a nasty sting which has earned them their common name.

Examine specimens of the hydrozoan *Millepora alcicornis,* commonly known as fire coral or stinging coral. Note that the corallites have two different sized openings and that no septae are present. The larger openings (GASTROPORES) are produced by feeding polyps, while the smaller openings (DACTYLOPORES) are produced by stinging polyps.

CLASS ANTHOZOA

SUBCLASS OCTOCORALLIA (Alcyonaria): "sea whips" and "sea fans". These cnidarians do not produce a solid mineral skeleton, but rather secrete spicules that are imbedded in organic material. Why do you suppose they are relatively unimportant in the fossil record?

SUBCLASS ZOANTHARIA - sea anemones, true corals. Mesentaries paired in cycles of 4, 6 or 8; in corals the mesentaries secrete calcareous septa

ORDER ACTINARIA - sea anemones.

Metridium (Recent). Grows to heights of 2 m. We will dissect specimens of *Metridium* as an example of general coral soft part anatomy (see lab appendix A). Lacking hard parts, anemones have virtually no fossil record except for some trace fossils possibly produced by burrowing anemones.

ORDER SCLERACTINIA (M. Tr. - R). True corals and hexacorals. Six primary septa characterize the scleractinians; other septa added in cycles of six; solitary or colonial; exclusively marine

1. Examine the scleractinian genera *Acropora* (staghorn coral), *Diploria* (brain coral), *Montastrea* (common star coral), and *Porites* (finger coral). These are all important reef-forming corals in modern tropical marine, shallow water environments. Sketch each and label corallites, coralla and septae.

ORDERS RUGOSA and TABULATA. Both of these groups are restricted to the Paleozoic and are of major importance in the framework construction of Silurian and

Devonian reefs. It is generally believed that rugosans and tabulates did not harbor symbiotic algae in their soft tissues as do scleractinians; thus these groups cannot be considered true hermatypic corals. Most coralla of these groups are small in comparison to the massive structures built by scleractinians, although some reefs constructed by rugosans and tabulates are of considerable size. Examine the following specimens of the following taxa which illustrate the principal morphologic features of these groups

ORDER RUGOSA (M. Ord. - Perm.) - Six primary septa, others added in cycles of four; solitary, compound, or colonial; skeleton calcitic. See Beerbower p. 253 or Boardman et al. p. 146 for morphologic terms applied to rugosans. Commonly called tetracorals, horn corals, or cup corals.

2. Important rugose coral index fossils.

a. *Aulophyllum* (Dev.) - Examine external morphology. Note well-developed epitheca with concentric wrinkling, denoting growth lines. Some rugose corals show what are believed to be daily growth bands, plus more widely spaced bands that may be monthly and annual. Using such specimens it has been found that the number of days/year has not always been 365! Sketch and label features of the skeleton that you can identify.

b. *Zaphrentis* (Dev.) - Examine the well-preserved, smaller coralla closely. The shallow depression into which you are looking is the CALICE. The CARDINAL SEPTUM is located within the CARDINAL FOSSULA (the gap between the septae).

c. *Benthamyphyllum* (Sil.). - Examine the cut specimen and note extreme development of dissepiments which confine the septa to the center of the calice. Sketch the larger specimen. Why is it "bent"?

d. Examine and sketch specimens of the colonial rugose corals *Hexagonaria* (Dev.), *Lithostrotion*ella(Miss.), and *Billingsastrea* (Dev.). Examine *Phillipstrea.* Do you dectect any difference in the separation of corallites between the four taxa?

ORDER TABULATA (M. Ord. - Perm.) - Calcareous skeleton with closely packed corallites varying from rounded to polygonal in transverse section; horizontal elements called TABULAE form at base of polyp at successive growth stages, giving longitudinal section of corallite a ladder-like appearance; exclusively colonial but varying in form to include massive, tubular, ramose, encrusting and chain-like colonies.

3. These cut specimens of *Favosites* (dominant Ord. - Dev.) beautifully illustrate classic features of tabulate corals, namely tabulae, mural pores, and relatively small (and often polygonal) corallites. Compare the colony form of *Favosites* to that of *Halysites* (Ord. - Sil.).u

Examine the various cut and polished specimens of *Favosites.* Label morphologic features (see a paleo text for a tabulate morphologic diagram). Answer as completely as possible the following questions:

1. How are new corallites added? (what is the pattern of corallite addition?).
2. Does tabulae formation occur simultaneously for the colony, or is it a random event?
3. do the tabulae give any evidence of colony form during successive growth stages? To answer this, try to trace tabulae across the corallum.
4. Look for overgrowths of new corallites over areas of the colony that were killed by sediment overwash. If present, describe briefly the pattern of new corallite addition around and over the overwash area.

COELENTERATA LAB APPENDIX A:
METRIDIUM DISSECTION

Phylum Coelenterata
Class Anthozoa
Subclass Zoantharia
Order Actiniaria - sea anemones, solitary, lacking hard parts
Genus *Metridium*

Sea anemones inhabit coastal waters throughout the world, and they are particularly abundant in tropical waters. They commonly are brightly colored. Anemones require a firm substrate for attachment and are commonly found attached to rocks and shells. A few forms are burrowers in sand and mud.

Obtain a specimen of the sea anemone, **Metridium**, and study its external morphology. Identify the COLUMN, ORAL DISC, and PEDAL DISC. Numerous simple, hollow TENTACLES arise from the ORAL DISC. Find the slit-shaped MOUTH, which bears at both end ciliated grooves called SIPHONOGLYPHS (sometimes only one groove is present). These grooves permit circulation of water into the GASTROVASCULAR CAVITY. The slit-shaped mouth and siphonoglyphs superimpose a bilateral symmetry pattern on the initial radial pattern of the sea anemone. The column bears a circular fold at its junction with the oral disc. This fold is known as the COLLAR, and it covers the oral surface when the animal contracts.

DISSECTION DIRECTIONS:

1. Make a cross-sectional cut (like Diagram B) through your specimen just below the collar fold, as shown in Diagram A (the dashed line).

2. On the lower part of the specimen, identify the siphonoglyphs in the oval-shaped PHARYNX. The cut through the column wall will reveal two layers of body tissue, the EPIDERMIS and the GASTRODERMIS. An intermediate filling of MESENCHYME (= mesoglea) occupies the remaining space.

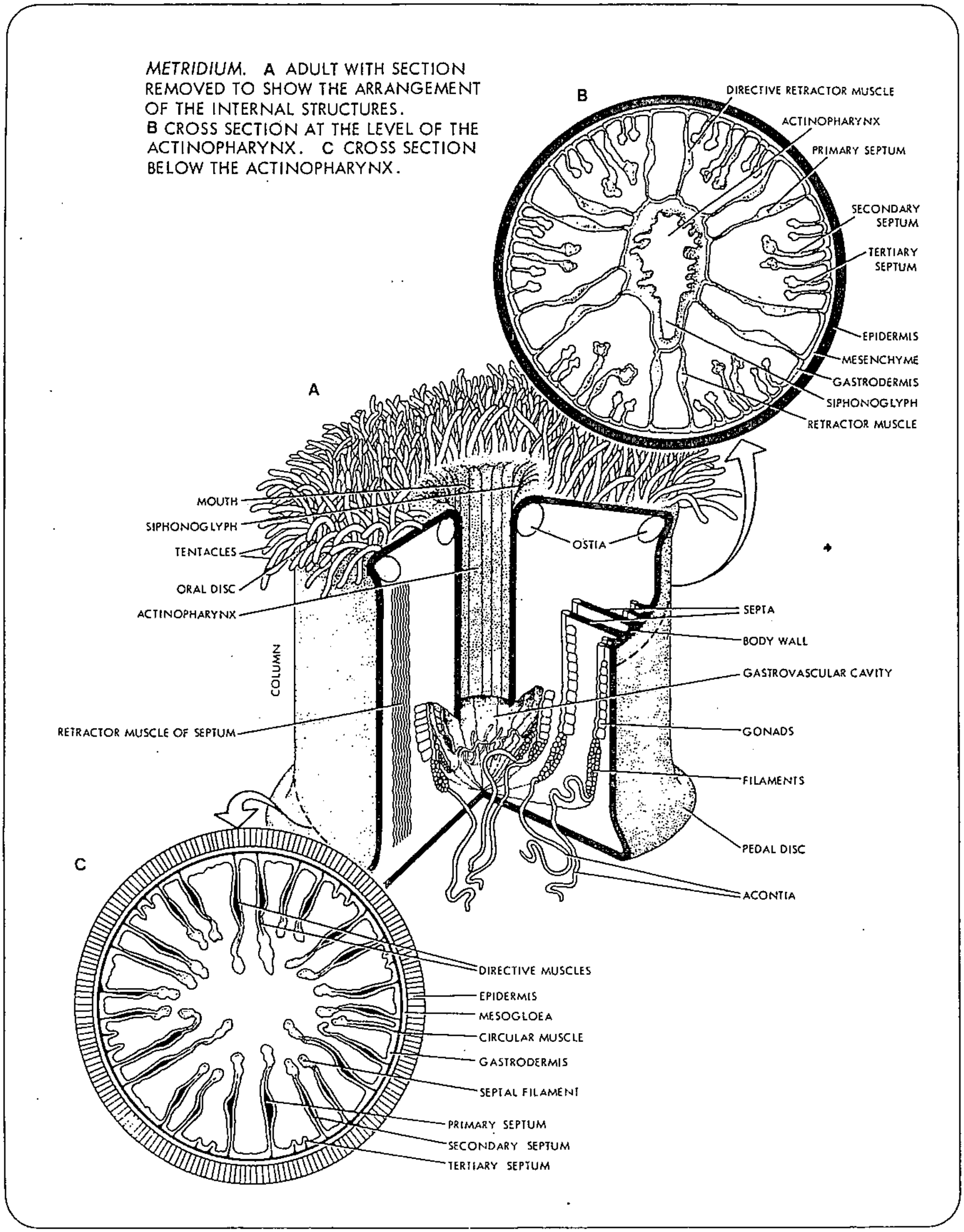
3. The gastrovascular cavity is partitioned by longitudinal, radiating SEPTA. The cavity can be revealed by making a cross-sectional cut as shown in Diagram C. There are both complete and incomplete septa. Complete septa are connected to the body wall and the wall of the pharynx. Ideally there are six pairs of complete (primary) septa, including two pairs of septa attached to the siphonoglyphs called DIRECTIVES.

Coelenterata Lab Appendix A:
Metridium Dissection

The free margins of incomplete septa form tri-lobed septal filaments. The outer lobes are covered with flagellated cells that aid in water circulation. The middle lobe contains NEMATOCYSTS and enzyme-secreting cells. Middle lobes extend below the pharynx and continue as thread-like projections called ACONTIA into the lower part of the gastrovascular cavity. The acontia produce enzymes for extra-cellular digestion.

4. Note RETRACTOR MUSCLES on the sides of the septa. GONADS are in the gastrodermis and lie on the septa in longitudinal bands behind the septal filaments.

5. Make cross-sectional cuts of some of the tentacles, and note that they are hollow. How is movement of the tentacles controlled?



Morphology of the sea anemone *Metridium*

GEOLOGY 217: BRACHIOPODA

You should be familiar with the following terms:

SOFT PART ANATOMY:
mantle

lophophore
pedicle
adductor muscle
diductor muscle
adjustor muscle

SKELETAL MORPHOLOGY:
brachial (dorsal) valve
pedicle (ventral) valve

EXTERNAL FEATURES:
commissure
hinge
umbo
beak
pedicle foramen
delthyrium
notothyrium
interarea
fold
sulcus
plication
costae

INTERNAL FEATURES:
hinge teeth
dental sockets
muscle scars
cardinal process
spondylium
brachidium
spiralium

SHELL STRUCTURE:
punctate shell
impunctate shell
pseudopunctate shell

SHELL FORM:
biconvex
planoconvex
concavoconvex
strophic hinge
nonstrophic (astrophic) hinge

Brachiopods are one of the most important groups of fossil marine invertebrates although they are of minor importance in the modern marine biota. Brachiopods are characterized by an external calcareous shell of two unequal valves which are symmetrical about a plane passing through the anterior-posterior axis, bisecting both valves. In contrast, bivalved mollusks (pelecypods) have equivalved shells which are symmetrical about a plane passing between the two valves. The brachiopod shell encases a unique food gathering and respiratory structure called the LOPHOPHORE. Brachiopods are attached to the substratum during all or part of their life cycle by a fleshy stalk called the PEDICLE.

There are two classes of brachiopods, the Articulata and the Inarticulata. Both have many fossil representatives although the focus of this lab is primarily on the Articulata. Use the glossary in Beerbower (p. 283-285) and the chapter in Boardman *et al.* as references to the cumbersome terminology associated with brachiopods.

PART I: Wall structure, internal structure, and soft parts.

Brachiopod Lab Appendix A: *Terebratalia* Dissection

Phylum Brachiopoda
Class Articulata
Order Terebratulida
Terebratalia transversa

Obtain a specimen of the Pacific brachiopod *Terebratalia transversa* for dissection.

Examine the brachiopod carefully and identify the following features: pedicle valve, brachial valve, pedicle, pedicle foramen, umbo, interarea, commissure, fold, sulcus, and costae. Locate plane of bilateral symmetry passing through anterior-posterior axis. How symmetrical are the halves on either side of this plane? Compare your specimen to others and note degree of individual variation in shell form.

Sketch the outline of the shell in three views: pedicle, brachial and lateral. Label anterior and posterior ends as well as features noted above.

Examine shell surface under the scope. What details do you see? Sketch a small area as seen under the scope. Note pore-like features: what are these called and what function(s) might they have?

Hold the animal with the ventral valve uppermost. Insert a scalpel between the ventral valve and the body of the animal, and work it against the posterior part of the ventral valve, cutting the adductor and diductor muscles away from this valve. Pull the valves apart, leaving the animal in the smaller dorsal valve. It is attached to this valve by the calcareous loop whcih supports the lophophore.

On the dorsal valve, identify the cardinal process and the hinge line. Now find, on the ventral valve, the two hinge teeth. Observe the relationship of the cardinal process and hinge teeth. Note the pedicle and the foramen through which it passes.

Identify the paired adductor and diductor muscles. What are the functions of these two muscle sets? The tentacle-bearing lophophore consists of two horseshoe-shaped lateral arms and a median process which coils anteriorly and dorsally. Locate the calcareous loop which supports the lophophore (brachidium). On each arm of the lophophore there is a groove which leads to the mouth situated in the posterior part of the lophophore; anterior to the mouth there is a prominent lip.

Make a cut in the mid-line through the coiled proces of the lophophore in order to see the extent of its coiling.

Scrape away the lophphore and soft tissue to observe muscle attachment sites. Proceed with the remainder of the lab exercise.

PART II Characteristics of fossil brachiopods

Class Inarticulata: Chitino-phosphatic shell (some calcareous with proteins), valves held together by complex musculature system, lacking dentition, lacking lophophore support structure, alimentary canal with anus. C-R, 220 genera.

Order Acrotretida

1. *Petrocrania* - a common encrusting inarticulate brachiopod, common in Ordovician strata.

Order Lingulida

2. Lingula – a relatively common "living fossil" that have remained virtually unchanged since Cambrian time. This brachiopod lives buried in mudflats, attached by a long pedicle.

Class Articulata: Shell calcareous, well developed teeth & sockets, commonly with brachidium (support for lophophore), paired adductor and diductor muscles. Diductor muscles inserted on cardinal process of brachial valve, alimentary canal without anus. C to R.

There are six orders of articulate brachiopods; you should be able to distinguish between them on the basis of morphologies presented below.

Order Orthida: unequally biconvex shells with well developed interareas, long hinge line; delthyruim and notothyruim commonly open, triangular; interior structures usually simple, shell impunctate or punctate. C to P, 340 genera.

2. Sketch *Dinorthis*, and label features (interarea, brachial valve, pedicle valve, delthryuim and notothyruim where available).

Order Strophomenida: Plano- to concavo-convex, less commonly biconvex; foramen generally closed in adults; free, cemented or attached by spines; generally elaborate cardinal process, pseudopunctate shell structure. O to Lower Jurassic, 865 genera.

3. Sketch any of the strophomenids on display and label the features that are present. Don't forget to include the name of the specimen with your sketch. What type of environment/substrate are these shell forms adapted for?

Order Pentamerida: generally biconvex shells with pedicle spondylium, commonly open or partially-closed delthyruim, brachiophores supported by plates, impuncate shell structure. middle C to D, 160 genera.

4. *Pentamerus* -- how is this fossil preserved? Sketch and label brachial and pedicle valves. Note the indentation towards the beak of the pedicle valve, which is a mold of the spondylium. Possession of a spondylium is characteristic of this order. What was its function?

Order Rhynchonellida: strongly biconvex shells with functional pedicle, partially closed delthyruim, usually strongly costate, highly sulcate, hinge line short, interareas lacking, impunctate shell structure. O to R, 520 genera.

5. Sketch one of these Rhynchonellids and label brachial and pedicle valves, fold, sulcus, costae and plications.

Order Spiriferida: mostly biconvex shells with spiral brachidium, delthyruim open or closed, circular foramen present or absent; impunctate or puncate structure. O to J, 720 genera.

There are three suborders discussed in the text, but we will only consider two varieties of spirifers: long and short hingeline forms.

6. Long hinged spirifers (Suborder Spiriferidina). Sketch and label *Neospirifer*. How is the specimen of *Paraspirifer* preserved? What is the structure preserved in the interior? What is was its function?

7. Short hinged spirifers (two suborders). Sketch and label *Atrypidina*.

Order Terebratulida: mainly doubly convex, smooth, costate or plicate shells with functional pedicle, looped brachidium (see Station 3), prominent pedicle beak, truncated by circular foramen, short hinge line, diminutive interareas, punctate shell. D to R, 540 genera.

8. No review of brachipods is complete without a specimen of *Terebratula,* the genus that designates this phylum as "lamp shells". Do you think that name is appropriate? Note the well-developed pedicle foramen.

GEOLOGY 217: BRYOZOA

You should be familiar with the following terms.

Soft part anatomy:

zoid
lophophore
avicularium

Skeletal morphology:

zooarium (zooaria)
zooecium (zooecia)
autopore
mesopore
diaphragm
cystiphragm
ectozone (mature region)
endozone (immature region)
aperture

Bryozoans (colloquially known as "bryos" or "moss animals") are aquatic colonial lophophorates that secrete external skeletons that may be calcareous. Most bryos are marine, although one group occurs in fresh water. Most Recent bryos prefer very warm shallow marine environments located a fair distance from river estuaries which would disturb these tiny animals with suspended sediment that could clog their apertures. By inference from the Recent habitats, we assume that fossil bryozoans lived in similar environments in the geologic past. Zooarial (colonial) form can be strongly influenced by environmental factors and thus shows considerable ecophenotypic variation within individual species. As a result, external form is rarely a reliable guide to identification and classification, but may be indicative of environmental conditions. For example, bryozoans that anchor themselves by encrustation on already dead shells on the sea floor usually indicate fairly high energy, whereas lace forms or other delicate twig-like colonies would naturally be destroyed in agitated conditions and must have lived in more tranquil waters. Taxonomy is based on internal features which must be studied in thin section under the microscope. The result of these difficulties in identification combines with the small size and relatively slow evolution of bryozoans to detract from their use in biostratigraphy.

The bryozoan animal (ZOOID) exhibits the triploblastic grade of organization, that is, they have three cell layers: ectoderm, endoderm, and mesoderm between the first two layers. They possess definite organs. As with brachiopods, bryozoans utilize a LOPHOPHORE (a ring of ciliated tentacles surrounding the mouth) for feeding. Feeding zooids possess a mouth that leads to a U-shaped digestive tract that includes an esophagus, stomach, intestine and rectum (see class handout). The anus opens outside the lophophore ring; hence the other commonly used name for bryozoans, ectoprocts. The commonly calcified zooecium within which the zooid resides serves not only for protection but as an attachment site for muscles to control retraction and eversion of the polypide (the part of the zooid containing the lophophore, mouth and foregut region). A nervous system is present although a vascular system is absent. Most bryozoans are HERMAPHRODITIC (bisexual) and thus zooids develop both ovaries and testis. Fertilized eggs remain within the bryozoans until they mature into a larva which is released to become free-swimming. Upon settlement, the larva becomes the first individual (ANCESTRULA) of a new colony. The colony grows by asexual budding of the ancestrula.

The bryozoan classification used here follows the revised Part G of the Treatise on Invertebrate Paleontology. Study the following specimens and use references as indicated.

CLASS PHYLACTOLAEMATA (Cret.? - Rec.) - Fresh water bryozoans that are uncalcified. Lophophore horseshoe-shaped; mouth protected by an overhanging lip, the epistome; zooid degenerates into a statoblast (a resting stage encased in a chitinous sheath) during unfavorable periods; poor fossil record.

1. *Pectinatella*

CLASS STENOLAEMATA (U. Cam.?, Ord.- Rec.) - Majority of fossil bryozoans occurring from the Ordovician - Cretaceous. Marine only; calcified tubular zooecia fused with adjacent zooecia; zooecia show two ontogenetic regions: 1) Endozone, the immature region with thin walls and sparse intrazooecial structures such as diaphragms, and 2) Ectozone, the outer, mature region with thick walls and more closely spaced intrazooecial structures; 3 of the 5 orders are available for display.

ORDER Tubuliporata (formerly Cyclostomata) Ord. - Rec. Circular aperture without an operculum; zooecia interconnected by pores but generally lack diaphragms.

1. *Stomatopora* - an encrusting bryozoan. Examine under the microscope under low power. Note the uniserial, subtubular zooecia that branch to form a pattern of indefinite polygons. The zooecia lack diaphragms and have simple apertures (see ML&F, p. 175-176). Sketch the specimen and label zooecia, zooaria and apertures. How was *Stomatopora* able to encrust this brachiopod? Was the brachiopod alive or dead when encrusted? Suggest a scenario.

2. *Evactinopora*-- a radiate form from Mississippian strata

3. *Hederella*, another encrusting tubuliporate. Compare this specimen to Stomatopora. Could the brachiopod here have been alive when it was encrusted? Why?

ORDER Trepostomata (Ord. - Perm.) - Long tubular zooecia with circular or polygonal apertures and numerous diaphragms; well developed ectozone and endozone; zoarial form variable but often massive, foliaceous or ramose.

4. *Prasopora* - Study the hand specimens and thin sections. In specimen, note the autopores and mesopores. In thin section, note diaphragms, cystiphragms, immature and mature regions. See ML & F p. 165 for a discussion of morphology of *Prasopora*, which is an Ordovician index fossil. Sketch and label the features mentioned above.

5. *Batostomella*- A branching trepostome

6. *Monticulipora sp.*and *Constellaria polystomella* - These ramose to massive bryozoans are characterized by having prominent monticules on the zooecial surface. Note the stellate form of the monticules on *Constellaria*. They are formed by clusters of mesopores surrounded by unusually large autopores. Both genera are good index fossils for the Ordovician period. Sketch one of these genera and label the mesopores, monticules and autopores.

ORDER Fenestrata (Ord. - Perm) - Until recently included with cryptostomes. Zooecia flask-shaped; apertures ringed by a rim or PERISTOME; zooecia arranged along one side of branches (OBVERSE side) that are connected by crossbars (dissepiments). The other side of the colony (REVERSE side) contains no autopores. Zooaria typically have a delicate frondose form.

7. *Fenestella* - Study under low power magnification. This is the reverse side of the colony. The zooids occupied zooecia along the margins of the "windows" rather than the "window"s themselves, but they did so on the other side (the obverse side) only. See ML & F p.

171-172 for discussion of the morphology. Fenestrate bryozoa are common in middle and upper Paleozoic rocks.

8.*Archimedes sp.*- Important Upper Mississippian index fossil, noted for a frondose, spiral zoarium that is usually preserved only as the more resistant axes or screws. See ML & F, p. 171-173 for discussion of spiral-shaped fossils. Compare the lace-like habit of both of these fenestrate bryos to the more robust forms. Why is this growth form efficient for feeding? What are the disadvantages of this colonial form?

CLASS GYMNOLAEMATA (Ord. - Rec.) - Primarily marine bryozoans which are not always calcified; strongly polymorphic; have a circular lophophore. One of the two orders is available for examination.

ORDER Cheilostomata (Ord. - Rec.) - Dominant Recent marine bryozoan group. Zooecia calcareous, box-like with hinged operculum; well developed polymorphism (avicularia, vibracula, ovicells).

9. Study the encrusting cheilostomes under low power magnification. Representatives of this order are characterized by having short zooecia with small apertures, commonly surrounded by an elevated rim called the PERISTOME.

GEOLOGY 217: MOLLUSCA: BIVALVIA

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You should know the following terms:

byssus	hinge teeth and sockets
siphons	plicae
palps	costae
muscle scars	ligaments
monomyarian	growth lines
isomyarian	right and left valves
anisomyarian	anterior, posterior
pallial line	dorsal, ventral
pallial sinus	beak
adductor muscles	foot

The bivalves comprise a highly diversified group of aquatic organisms, most of which are marine vagrant benthon, some are nektic and some are sessile. The structural and anatomic organization of bivalves is illustrated by both lecture and lab handouts. Bivalves have no head, but most have a large muscular foot for locomotion. They possess a visceral system with an anterior mouth and posterior anus. Zoologists classify bivalves on the basis of four distinct types of gills that, for obvious reasons, are of little use for the paleontologist. The gills are always paired and positioned laterally to the visceral tract. Water carrying oxygen and food particles may be drawn into the mantle cavity between the two laterally oriented shells by means of posterior tubes (siphons) in advanced bivalves.

The bivalved shells are secreted by the ectodermal mantle in a shingle-like fashion starting from the post-larval proto-valves and growing to the anterior, ventral and posterior margins. In most bivalves, the valves are held together by teeth and complimentary sockets forming a hinge in the cardinal area (see Beerbower, p. 347-350). Paleontologists frequently use the different types of hinge dentitions for taxonomic purposes since these calcareous structures are fossilized. A muscle-like band in the cardinal area, the ligament, is under minimal strain when both valves are opened. One or two adductor muscles contract to close the valves and place the ligament under strain. When the adductors relax, the shell opens. The bivalve shell is normally oriented with the hinge and cardinal area dorsal and with the beak pointed anteriorly. Thus, one discriminates between a right valve and a left valve when the shell is viewed from the posterior (analogous to the right and left rear fenders of a car). The symmetry axis, therefore, lies between the two valves, each valve being the mirror image of the other.

The functional morphology, paleoecology and evolution of bivalve molluscs are better understood than for most other fossil invertebrates. One reason for this is that the relations between preservable hard part structures, soft part anatomy and living habits have been well-studied in living bivalves. A second reason is that most major groups of living bivalves have long fossil histories (see Stanley, 1968), suggesting that these groups have been conservative in form and function over long spans of geologic time. Consequently, a solid understanding of form and function in living bivalves is essential to study of extinct forms.

I. Dissection of *Mercenaria*. See appendix.

II. Bivalve classification is based to a great extent on hinge structure and dentition. Examine the study collection of dentition types that is displayed in the same order as given by the classification summary and the consequent assignment of genera to bivalve orders (see your text, Fig. 15.13, or Beerbower for illustrations of dentition architecture). Sketch an example of each order, and label dentition type. Answer any additional questions listed.

PHYLUM MOLLUSCA

CLASS BIVALVIA (PELECYPODA)

Summary of classification, characteristics and geologic ranges of orders of Bivalves.

Classification of bivalves to Ordinal level is based on three major morphologic characteristics.

A. Gill Structure -- see handout sheet on gill structure.

B. Dentition form -- see the lab study set of different dentition types. See also your text.

C. Shell microstructure -- basis for defining the two subclasses, see below.

SUBCLASS PRIONODESMACEA (O-R)

3-layered CaCo3 shell stucture: outer periostracum layer, middle thick layer, and inner, lamellar layer. A thin nacreous layer of aragonite may form a 4th, innermost layer.

1. ORDER PALAEOCONCHA (O-R; dominant O-D)

Protobranch Gills; hinge teeth poorly developed;; valves held together by ligament and adductor muscles.

Grammysia

2. ORDER TAXODONTA (O-R)

Protobranch and filibranch (dominant) gills; numerous small teeth along hinge line.

All arc shells *Arca*

3. ORDER SCHIZODONTA (O-R)

Filibranch gill, 2 prominent teeth diverge from beneath beak on one valve, Y-shaped tooth on other valve, tight articulation.

Arodontia

4. ORDER DYSODONTA (O-R)

Filibranch and eulamellibranch gills; lack hinge teeth but bear a highly modified ligament, part of which (the resilium) lies inside the hinge line and is compressed when valves are shut. Usually possess only one adductor muscle.

Scallops - The pectins are monomyarians, and the single large adductor is a common sea food, the scallop. Note the symmetry of these pectinids. What does the symmetry indicate about the life mode of these forms?

Oysters (e.g,. *Crassostrea* and mussels e.g., *Mytilus*)

5. ORDER ISODONTA (TR-R)

Filibranch gills; derived from dysodonts; two small subequal teeth and resilium.

Spondylus

SUBCLASS TELEODESMACEA (O-R)

Shells lack prismatic layer (thus have a two-layered structure); eulamellibranch gills dominant (a few, borer, clams have septibranch gills); hinge teeth and siphons well developed.

6. ORDER HETERODONTA (S-R)

Well developed cardinal and lateral teeth, pallial line

Mercenaria - How does the form and function of the shell differ from that of typical brachiopods (e.g symmetry, mineral composition, musculature etc.)?

Cardium
Nemocardium

7. ORDER PACHYDONTA (J-R)

Thick, highly unequal valves; thick teeth (modified from heterodont pattern); sessile life mode.

The Rudists – The rudistids were unusual bivalves which developed massive attached shells. Some built reef-like structures in warm, tropical areas during the Cretaceous. In what environment would such a massive shell be advantageous? I do not have great examples of rudist bivalves for exhibit. These are very small specimens of a remarkable group. **Please see the article by Claudia Johnson included with the lab set.**

8. ORDER DESMODONTA (O-R)

Teeth weak or lacking; have spoon shaped resilifer to hold internal ligament (resilium); includes one order of borer clams

Amiantis
Unlabelled shell

Bivalve Lab Appendix: Dissection of *Mercenaria*

Obtain a specimen of the quahog clam *Mercenaria mercenaria*, for dissection. The quahog is an active, shallow marine burrower in soft, sandy sediment. *M. mercenaria* lies near the surface when feeding with its siphons extended above the sediment water interface, but, when the tide recedes, it burrows deeply.

Examine the valves which are on either side of the body and are attached along the hinge line by the ligament. Note growth lines, fragments of the outer periostracum shell layer (dark), and the underlying calcareous layer. Sketch the clam and label right and left valves, anterior, posterior, dorsal and ventral.

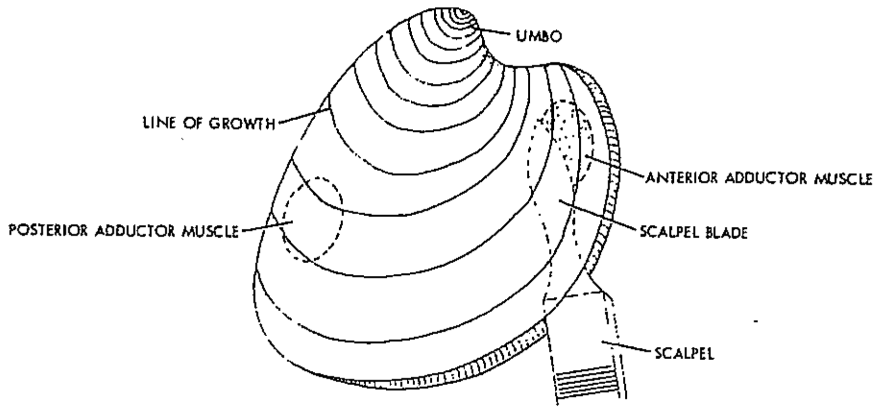
Carefully open the valves until the soft parts inside can be seen. Hold the animal with the left valve uppermost. Note the mantle, the membrane just inside the valve and attached near the valve edge (this layer secretes the shell).

Use a scalpel to separate the mantle from the left valve. Sever the anterior and posterior adductor muscles. These muscles are used to close the valves. Note the cardinal teeth found on the hinge line and how the valves fit together. Separate the left valve. Sketch its interior and label cardinal area, beak, pallial line, pallial sinus, anterior and posterior muscle scars.

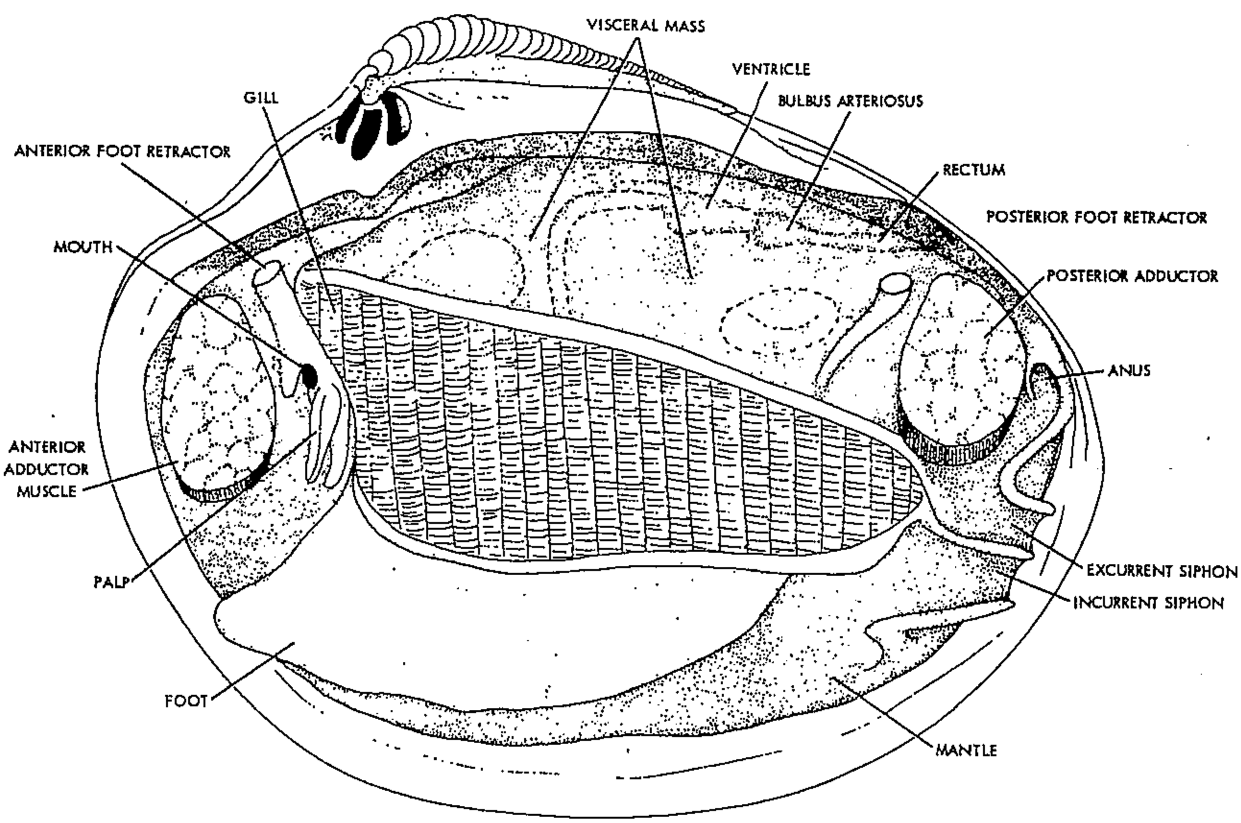
Examine the mantle lobe, noting that on its dorsal side it is fused to the opposite mantle lobe. The ventral edge of the mantle is free, and the mantle is attached ventrally along the pallial line. The posterior margins of the mantle are thickened and are united to form two siphons. Water enters through the ventral (incurrent) siphon and exits through the dorsal (excurrent) siphon.

Carefully remove the left mantle. Locate the visceral mass and the muscular foot. The gills (ctenidia) are located on either side of the visceral mass. The gills are composed of filaments which are fused to form an outer and inner lamella. Examine the thin section of eulamellibranch gills to observe details of gill structure (see class handout).

Find the paired labial palps anterior to the gills. Cilia move food from the gills along deep food grooves on the palps to the mouth. Cut away the gill and expose the visceral mass. Shave off thin slices of the visceral mass and the dorsal part of the foot. Locate the looping intestine embedded in the whitish or cream-colored gonad. Try to trace the intestine anteriorly to the stomach. The stomach is embedded in greenish digestive gland (liver).

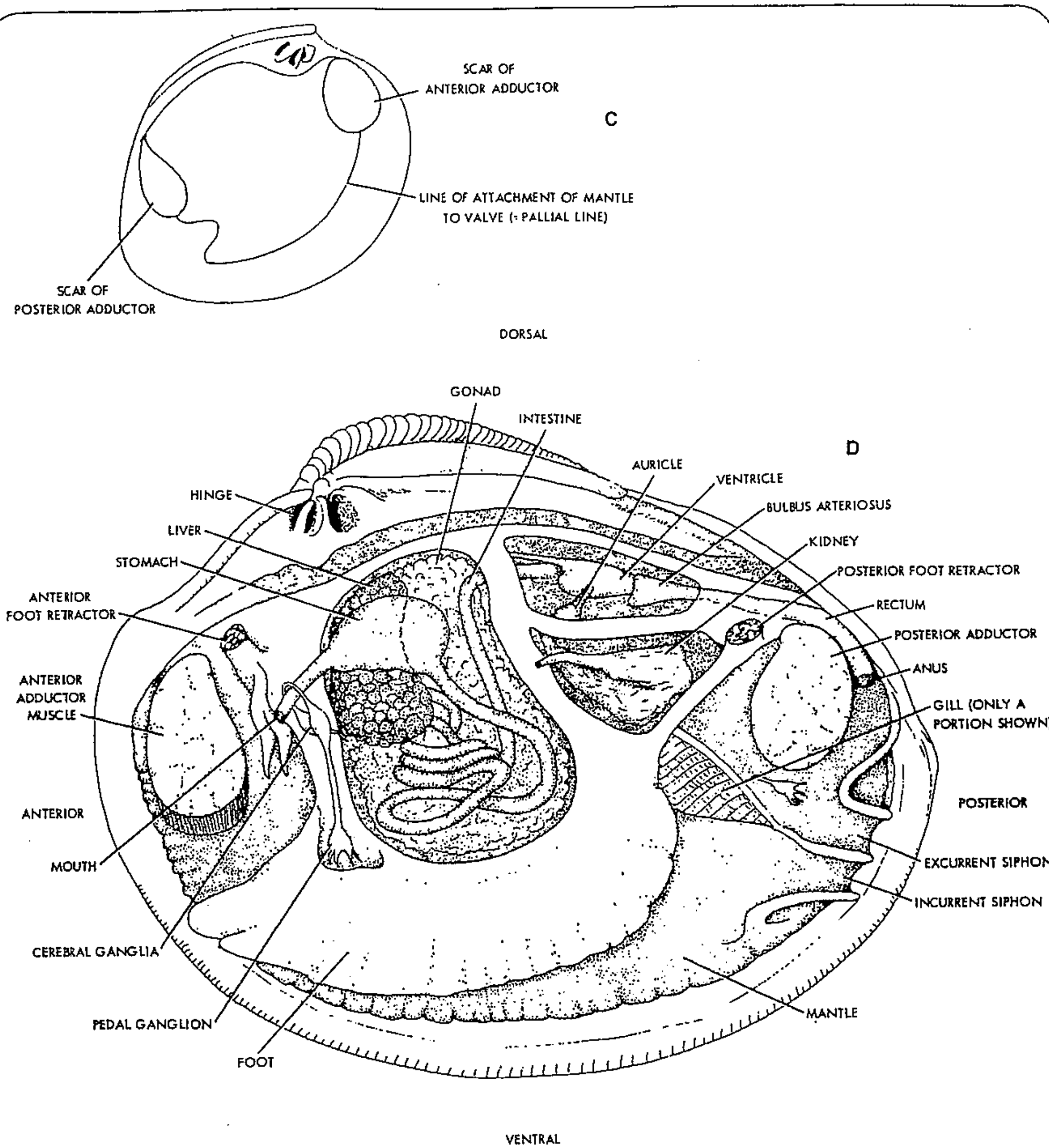


A



B

MORPHOLOGY OF *Mercenaria mercenaria*



MERCENARIA (VENUS). **A** EXTERNAL FEATURES AND METHOD OF INSERTING A SCALPEL TO CUT THE ADDUCTOR MUSCLES. **B** WITH THE LEFT VALVE AND MANTLE REMOVED. **C** VIEW OF THE INSIDE OF THE LEFT VALVE. **D** INTERNAL ANATOMY. THE LEFT VALVE, MANTLE, GILLS, AND TISSUES OVERLYING THE INTERNAL ORGANS HAVE ALL BEEN CAREFULLY REMOVED.

GEOLOGY 217: GASTROPODS AND CEPHALOPODS

PART I: Gastropods

Most Gastropods have torsion in common: the body of the gastropod is organized in such a way that the originally posterior end with the anus and gills is twisted around to become positioned above the head region (See class handout). Gastropods inhabit a great variety of environments. Most are aquatic, marine or limnic (lake-dwelling), but a large number have become adapted to life on land (the Subclass Pulmonata - which has developed lungs instead of gills). Gastropods are herbivorous and carnivorous.

The gastropods have been unusually successful in adapting to the diverse environments on earth. They have adapted to all of the basic modes of life in the sea and have successfully colonized fresh water and terrestrial environments. Because of their wide ecologic range and their preservable shell, gastropods are potentially the most useful of all invertebrate fossil groups for environmental reconstruction.

Prosobranch gastropods (Subclass Prosobranchia) are classified in three orders (Archaeogastropoda, Mesogastropoda, and Neogastropoda) primarily on the basis of gill structure and position. Shell form is variable, but in general Archaeogastropods have cap-shaped, planispirally coiled, or conispirally coiled shells, the latter with a notch or slit on the outer lip extending to a sharply defined band parallel to the coiling whorls (SELENIZONE). Mesogastropod shells vary in coiling from low to high spired and generally lack a siphonal notch or canal. Neogastropod shells normally have a well-developed siphonal notch or canal.

1. Examine shells of the gastropod genus *Busycon*. Use one of the *Busycon* shells as a model to familiarize yourself with the gastropod morphologic terms listed below (see available references in lab and the class handout) (i.e. sketch and label one of the specimens).

Aperture
Anterior
Posterior
Apex
Spire
Protoconch
Suture
Columella

Inner lip
Outer lip
Siphonal canal
(if reduced in
size, termed
siphonal notch)
Body whorl

2. *Sphenosphaera* and *Maclurites* are primitive gastropods from the early Paleozoic. How are they coiled?

3. *Haliotus* is characterized by a high rate of whorl expansion an one or more openings in the shell. What was the function of the holes (hint, this is an Archaeogastropod)? What does the high rate of whorl expansion indicate about the life mode of the organism?

4. The basic pattern of growth in coiled shells has been described by Raup using four variables: 1) the shape of the generating curve, 2) the rate of increase in size of the generating curve (i.e. rate of whorl expansion), 3) the rate of whorl translation, and 4) the distance of the generating curve from the coiling axis. Compare the four specimens in tabular form and describe how each variable influences shell shape.

5. What do these structures (borings) indicate about the feeding habit of some gastropods? How do you suppose the borings were produced by these gastropods? The cone shell, Conus, is an example of a predatory gastropod. In addition to their ability to bore through shell material, members of this genus secrete a highly toxic substance to stun or kill their prey. In fact, a sting from some of the cone shells in the Indo-Pacific region will kill a full grown human.

Part II: Cephalopoda

You should be familiar with the following terms (see class handout).

camera
septum
body chamber
phragmacone
siphuncle
septal neck
suture:
- goniatite
- ceratite
- ammonite

saddle
lobe
evolute
advolute
involute
convolute

orthocone
cyrtocone
longicone
brevicone
ectocochliate
endocochliate
cuttlebone
guard (rostrum)

Although morphologically diverse throughout their long stratigraphic range, cephalopods are quite restricted ecologically. All living forms (and presumably all fossil forms as well) are nektic animals inhabiting open oceans (neritic and pelagic zones). They are found today throughout the world's oceans in warm and cold waters over a wide depth range.

Among the living forms are the squids, octopods, cuttlefish, and the pearly nautilus. The nautilus is the only living ectocochliate (having an external shell) cephalopod, the only survivor of the major fossil subclass Nautiloidea. Cephalopods provide many important index fossils: nautiloids during the Paleozoic and ammonoids during the late Paleozoic and especially during the Mesozoic.

Anatomically the cephalopods bear closest resemblance to the gastropods. In both groups the anterior-posterior axis of the body has been bent. In cephalopods, however, this bending brings the mantle cavity to face toward the anterior, but lying beneath the head. In gastropods, torsion brings the mantle cavity also to face toward the anterior, but to lie above the head. All cephalopods have a univalved tubular shell which may be straight (ORTHOCONIC), slightly curved (CYRTOCONIC), or coiled. Coiling is usually planispiral, although the heteromorphic ammonoids are bizarre exceptions.

The major feature of cephalopods is the development of chambers within the shell. Chambers are formed as the animal grows forward. Periodically the animal detaches the mantle from the last-formed septum and pulls the entire body forward within the body chamber. A new septum is then secreted by the mantle, forming a new chamber. However, the older, chambered part of the shell (PHRAGMACONE) remains connected to the body by means of the tubular SIPHUNCLE. In living nautilus, the siphuncle serves the vital function of replacing fluid within the chambers with gas, providing buoyancy to the animal. Presumably the siphuncle served the same function in ancient forms. Buoyancy, as provided by the chambered shell with siphuncle, enabled cephalopods to invade a new adaptive zone - that of nektic predatory life. Development of jet propulsion was a cephalopod innovation that also was an important element in their mode of life. Many other aspects of cephalopod morphology and physiology also reflect their adaptation as active predators. These include: highly developed image-forming eyes and other sensory capabilities, high metabolic rates resulting from an efficient closed circulatory system equipped with auxiliary branchial hearts, the ink sac, and the chitinous beak used in tearing flesh of the prey.

Cephalopod evolution is characterized by three major phases of adaptive radiation: the Paleozoic nautiloid radiation, the late Paleozoic through Mesozoic ammonoid radiation, and the coleoid radiation, extending from the Mesozoic through the present. Brief descriptions of the major subclasses are listed below with the study questions.

SUBCLASS NAUTILOIDEA (U. Cambrian - Recent)

1. *Nautilus* is the last representative of the Nautiloidea. Most conclusions concerning the paleobiology and paleoecology of fossil nautiloids are based on information gained from studies of specimens of this genus. Sketch a whole and sectioned specimen and label. Use class handout and available references (Beerbower, p. 362, fig. 16.1).

2. Many of the lower Paleozoic nautiloid shells were straight (orthoconic) or slightly curved (cyrtoconic) cones. If the camera were gas filled in these as they are in *Nautilus*, what was the life orientation of the animal? Examine the cut and polished specimens showing siphuncle structure and deposits. What function did siphuncle deposits serve?

SUBCLASS AMMONOIDEA

3. Examine a few of the specimens of Ammonoidea until you can distinguish the sutures from external ornamentation. Note when the shell substance is present, you cannot see the sutures. Ammonoids are subdivided according to the type of suture pattern that they display. Examine the following specimens and observe the suture plan that they display. Use Beerbower, p. 371, Fig. 16.6, as a reference. Sketch each suture type.

Meekoceras	Goniatite suture plan
Ceratites	Ceratite suture plan
Baculites *Placenticera*	ammonite suture plan

How are goniatites distinguished from nautiloids?

SUBCLASS COLEOIDEA

6. Examine the belemnoid *Hibolites*. This specimen shows remarkable preservation. Most belemnoids are preserved only by their internal skeletons. Belemnoids are important Mesozoic index fossils.

7. *Argonauta*. The "paper nautilus" is the external skeleton of a pelagic (open ocean) octopod. These are extremely fragile and seldom preserved.

8. Examine the internal, loosely coiled phragmacone of *Spirula*. This sepioid is a small, free swimming/floating cephalopod that lives in the pelagic zone of modern oceans (again see Boardman et al., p. 330, Fig. 14.46E).

GEOLOGY 217: ARTHROPODA

The diverse assemblage known as the arthropods (arthro-, joint; -pod, foot) is composed of organisms of highly varied form which have the following general characteristics: segmented body organization, a hard exoskeleton, and jointed appendages. Included within the arthropods are many common and well known forms such as insects, spiders, scorpions, centipedes, millipedes, lobsters, crabs, shrimps and extinct trilobites. Arthropods account for over 70% of all known vertebrate and invertebrate animals. The body segments (SOMITES or METAMERES) are bilaterally symmetrical and are movable on one another except where two or more somites are fused into tagmata. TAGMATIZATION (fusion) typically occurs in the head region but may also affect median and posterior regions. Each segment typically bears a pair of jointed appendages which are also covered with exoskeleton, although arthropods commonly display modification and reduction in number of appendages.

The exoskeleton is a protective chitinous covering formed by epidermal secretion (Fig. 1). The exoskeleton is layered, and the principal layer is often impregnated with calcium carbonate and phosphate. The hardened parts of the exoskeleton belonging to each metamere are called SCLERITES. Along articulating furrows between sclerites only the flexible chitinous layer and waxy outer coating are found, allowing flexibility of the articulation. The exoskeleton not only is a protective "suit of armor" for the arthropod, but it also furnishes support for the internal organs and attachment for the muscles.

Arthropod somites are named according to their location in distinct body regions. All have a head (CEPHALON) which is generally formed by fusion of six or more anterior somites. Posterior to the head there may be a median region termed the THORAX and then a posterior region called the ABDOMEN. In some crustaceans there is a fusion of cephalon and thorax, producing a CEPHALOTHORAX. Chitinous overgrowths which project over the head and enclose part or all of the thoracic and abdominal appendages are called a CARAPACE (found in ostracods).

Appendages vary greatly in number of segments, shape, size and function (Fig. 2). There are several common appendages: the antennae and antennules which are flexible slender sensory appendages, the mandibles, jawlike appendages bearing toothlike projections, the maxillae which are modified for passing food to the mouth, walking legs which may bear large pincers (CHELAE), and swimming appendages including PLEOPODS and UROPODS. Appendages may also be modified into gill structures as in the book gills of the horseshoe crab.

Vision is highly developed in arthropods and has been studied extensively. Two types of eyes may be present: the simple eye and the compound eye. The simple eye consists of a transparent lens above a crystalline cone which focuses light onto sensitive cells connected by nerve fibers to the brain. The compound eye is formed of numerous close-packed units, each acting as an individual lens connected to a retina of light sensitive cells.

The rigid exoskeleton cannot accomodate growth changes in the internal parts of the arthropod. Therefore the exoskeleton is periodically shed through the process of molting or ECDYSIS and a new exoskeleton is formed. Because of molting, arthropods potentially contribute several fossilizable remains to the sediment during their lives. Many arthropod fossils are pieces of these shed skins.

PART I Class Trilobita

You should be familiar with the following terms (see lecture notes):

- cephalon
- glabella
- fixed cheeks
- free cheeks
- genal angle
- facial sutures:
  - proparian
  - opisthoparian
  - gonatoparian
- enrollment
- thorax
- axial lobe
- pleural lobe
- pygidium
- holochroal eye
- schizochroal eye

The name trilobite stems from the latinized description of the typical morphology: three lobes. Although every trilobite has a distinct bilateral symmetry with an axis dividing the body into halves along a line from head to tail, there are three distinct parts to the exoskeleton: CEPHALON, THORAX, and PYGIDIUM. The three lobes are parallel to the axis of symmetry: a central AXIAL LOBE flanked by PLEURAL LOBES. Trilobites possessed an exoskeleton only on the dorsal side; the ventral side was more vulnerable with only a skinlike membrane and weakly protected appendages.

The trilobite cephalon in the most variable part of the exoskeleton. Ontogenetic stages are reflected in the rudimentary (non-functional) segmentation of the glabella. Cephalic morphology is useful in trilobite classification but is difficult to interpret in terms of life functions or habitats. Facial suture patterns were previously used as the single most important feature in classification, but this has been found to be unreliable, and now a number of features are used.

The cephalon usually has two facial sutures which are located in different positions depending on the type of trilobite (see class handout). Other sutures are located between cephalon and thorax, between individual thoracic segments, and between thorax and pygidium. Sutures probably functioned in providing flexibility between segments and in molting, by permitting splits in the skin through which the trilobite could emerge (see class handout). Flexibility was often sufficient to permit complete enrollment as protection for the ventral side.

1. Variation in morphology between trilobite genera is great. This variation permits subdivision of the class into seven orders (Treatise classification) and many families. Carefully examine the following trilobites. Sketch one plaster and one fossil specimen. For each specimen, label facial sutures (try to determine the type of suture), cephalon, glabella, free and fixed cheeks, axial lobe, pleural lobes, thorax and pygidium.

2. Examine the compound eyes of *Phacops rana*. What type of eye is this? Why is the compound eye effective in detecting motion?

3. Examine the plaster mold of*Cryptolithus tesselatus*. What mode of molting do you think this taxon utilizes? Evidence? Without biting or chewing appendages how did trilobites feed? How would you document your conclusion based on the features you observe on the cephalon?

4. Why did trilobites roll up? Under what conditions would they be preserved enrolled?

5. Examine specimens of *Agnostus*. These small trilobites are characterized by the absence of facial suture and eyes, the subequal size of the cephalon and pygidium, and a thorax consisting of only two segments. Suggest a probable life mode for these trilobites.

6. It is often stated that trilobites flourished in the Paleozoic but became extinct suddenly at the close of the Permian. Can you give a more accurate statement of their geologic distribution?

PART II - Other Arthropods

Subphylum Chelicerata. The chelicerates are characterized by their ventral appendages. Antennae are lacking, and the first appendages (chelicerae) are a pair with pincher claws adapted for feeding. These are followed on the underside of the PROSOMA (cephalothorax) by five pairs of unbranched legs. Included in the subphylum are spiders and scorpions (Class Arachnida), eurypterids and horseshoe crabs (Class Merostoma).

1. Horseshoe crabs (Subclass Xiphosura). Examine *Limulus*. *Limulus* has a semicircular prosoma articulating with a subtriangular opisthosoma and a strong telson (Fig. 3). Five pairs of walking legs are located posterior to the chelicerae on the underside of the prosoma. The first four pairs are alike, with chelae and having numerous spines on the median side which form gnathobases (for macerating food and moving it towards the mouth). The fifth pair of walking legs has a short spatulate process on the median side which is used for cleaning the gills. A degenerate pair of prosomal appendages forms the sixth pair of legs. The opisthosoma bears six pairs of appendages, the first of which forms the genital operculum and the rest are modified as book gills.

2. The eurypterids (Subclass Eurypterida) grew to giant proportions in Silurian seas. The prosoma bears all the appendages and the opisthosoma is appendageless (Fig. 4). Examine *Eurypterus*. These were common is Silurian rocks that were deposited in brackish or hypersaline environments.

Subphylum Crustacea. This subphylum coomprises the dominant marine arthropod groups such as lobsters, crabs, shrimp, crayfish ostracodes and barnacles. Crustaceans are characerized by possessing two pairs of antennae and three pairs of appendages specialized as jaw parts, all attached ventrally to the head.

3. Examine the slides of Cenozoic ostracodes and the rock slabs bearing the Devonian ostracode, *Leperdata alta*. Ostracodes are marine and freshwater crustaceans that enclose themselves in hinged, unequal calcareous valves. They are widely distributed microfossils and can be useful index fossils. How would you distinguish between an ostracode and a clam?

4. Examine specimens of the barnacle, *Balanus*, encrusting on shells of *Spisula*. Barnacles are aberrant crustaceans with a free swimming larval stage and attached adult stage. Barnacle plates are frequently preserved as fossils.

5. Think about arthropods. What are the advantages of an exoskeleton over an endoskeleton? Disadvantages?

ARTHROPODA

1

SOURCE: MLF, 1952

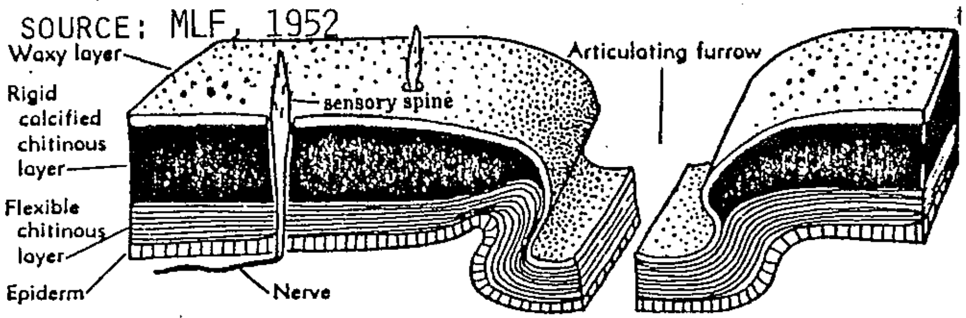


FIG. 12-2. Diagrammatic section of part of an arthropod exoskeleton.

2

SOURCE: MLF, 1952

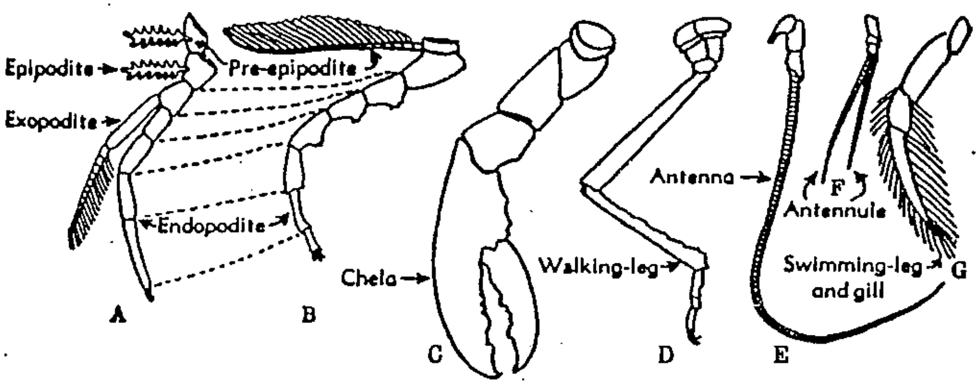
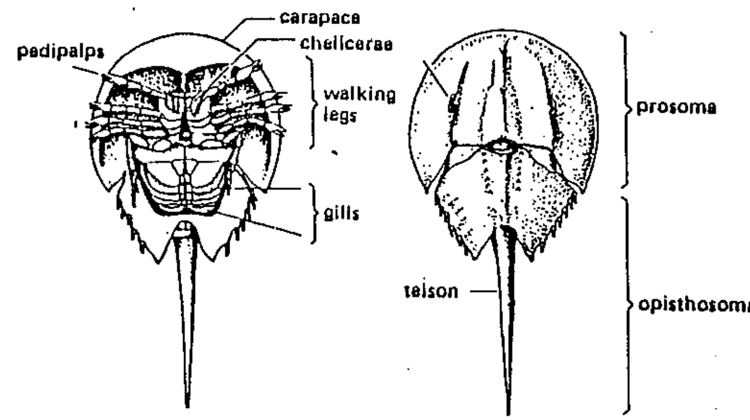


FIG. 12-5. Appendages of arthropods. (*A*) Generalized limb of a crustacean, showing branches from upper segments and biramous structure. (*B*) Trilobite limb, showing inferred homology with limb of a crustacean; the endopodite serves for walking, whereas the pre-epipodite is judged to have functioned for respiration and as a swimming organ. (*C*) Pincer-bearing appendage of a lobster. (*D*) Walking leg of an insect. (*E*) Antenna of a lobster. (*F*) Biramous antennules of a lobster. (*G*) Swimming leg of a water beetle.

3

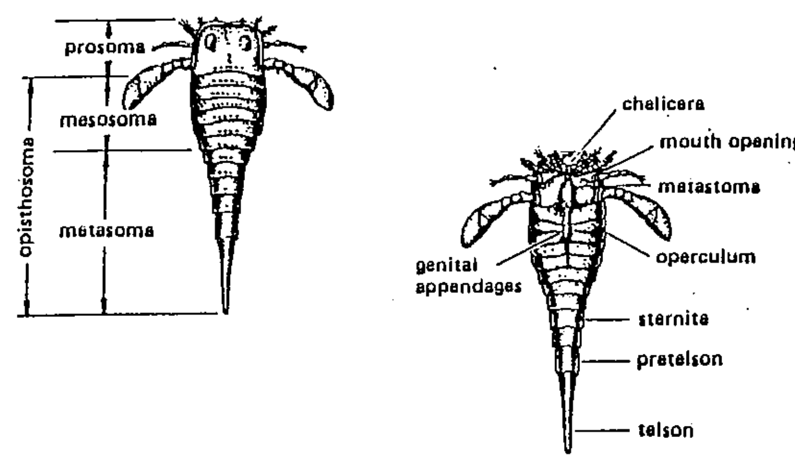
SOURCE: LEHMANN & HILLMER, 1983

Fig. 158. Subclass Xiphosura: *Limulus*, Recent. Left, ventral view; right, dorsal view (x 0.5).



4

Fig. 159. Subclass Eurypterida: *Eurypterus*. Left, dorsal view; right, ventral view (x 0.3).



GEOLOGY 217: ECHINODERMATA

The echinoderms stand apart from other invertebrates on the basis of their body plan (radial-pentameral, bilateral) and structural organization. All echinoderms except the holothurians (sea cucumbers) possess a skeleton composed of a large number of articulated plates (OSSICLES). The WATER VASCULAR SYSTEM in echinoderms is unique to the animal kingdom and functions in respiration, locomotion, food gathering and nutrient transfer. In early echinoderms (eocrinoids and cystoids) water was circulated through pores within the theca surrounding the body. Through time a more advanced system evolved by which water enters the water vascular system through a calcified tube (STONE CANAL) by ciliary action. The stone canal enters the RING CANAL surrounding the gut from which a series of RADIAL CANALS extend into the rays of the echinoderm. From the radial canals numerous lateral canals give rise to the TUBE FEET or PODIA. Depending on the group of echinoderms, tube feet may or may not have suckers at their ends and may or may not be equipped with internal bulblike AMPULLAE. The ampullae act as reservoirs for coelomic fluid which can be forced into the tube feet by ampullar contraction.

Another major characteristic of all echinoderms is the skeleton which is known as the STEREOM. Echinoderm stereom is formed within mesodermal tissue by the deposition of high-magnesium calcite in the form of a three dimensional lattice. Spaces within the lattice are occupied in life by mesodermal cells but after death and decay of tissues the stereom is highly porous. Each plate or ossicle is a single calcite crystal. Spines of various types and sizes are characteristic of the echinoderms and give them their name, "spiny-skinned".

Echinoderms are exclusively marine animals occurring in almost every environment from the intertidal to the deep sea, generally under normal salinities but occasionally in brackish water. The living echinoderms include five classes: the CRINOIDS (sea lillies and feather stars), living as suspension feeders, the OPHIUROIDS (brittle stars, serpent stars and basket stars) are detritus or suspension feeders, the ASTEROIDS (sea stars) living typically as predators but also in other modes, the ECHINOIDS (sea urchins, sand dollars) living as grazers, and HOLOTHURIANS living as deposit feeders and suspension feeders.

Echinoderms are deuterostome invertebrates. The similarities of their embryonic development to that of hemichordates and chordates suggests a close phylogenetic relationship between echinoderms and chordates.

Classification of echinoderms is based on: body symmetry, shape, arrangement of water vascular system, orientation of mouth and anus, number and arrangement of plates, and mode of growth. At one time echinoderms were merely divided into two subphyla: PELMATOZOA (stalked forms) and ELEUTHEROZOA (free-living forms). Because it is now realized that free-living forms evolved from stalked forms along several lines of echinoderm evolution, that simple breakdown has been abandoned. However, the terms pelmatozoan and eleutherozoan are still useful for describing life habits of particular groups.

PART I - SUBPHYLUM CRINOZOA

The following terms apply to the major pelmatozoan (stalk-bearing) groups .
("b" = blastoids)

theca
calyx
calyx plates:
infrabasals
basal
column (stalk, stem)
columnal

crown
arms:
uniserial arms
biserial arms
pinnules

holdfast
cirri
pelmatozoa
ambulacrum
brachioles (b)
hydrospires (b)
spiracles (b)
deltoids (b)
pore rhomb

A. **Class Cystoidea** (Ord.- Dev.)
(b)

1. Cystoids are characterized by thecae with an irregular arrangement of a variable number of plates and imperfect radial symmetry. Examine specimens of *Caryocrinites* (Ord. - Sil.). Use Beerbower, Fig. 17-4A, p. 389 as a reference to cystoid morphology. This is an "advanced" cystoid in that the pore rhombs are covered with plates along the the interplate suture and can only be seen in outline by the aligned rows of pores on the thecal plates. Find the stem attachment point and orient the specimen with mouth up and stem attachment down. More detailed features of morphology are not preserved on our specimens. What was the purpose of the pore rhomb system and brachioles? Refer to the Treatise vol S 1 (1) p. S223, Fig. 122 for photos of relatively complete specimens of this cystoid.

B. **Class Blastoidea** (Ord. - Perm.)

Blastoids are characterized by the regular arrangement of plates (13 or 14 in number) and radial symmetry. Ambulacra are large and bordered by numerous brachioles on either side.

2. Sketch a specimen of *Pentremites* and label the following features: ambulacral groove, spiracle, mouth, deltoid plates, radial plates, basal plates, brachiole attachment points (see Beerbower, Fig. 15-5, p. 392). Note complexity of the ambulacra with many side and cover plates. *Pentremites* is an excellent Mississippian index fossil.

C. **Class Crinoidea** (Ordovician - Recent)

Crinoids are characterized by thecae with circlets of radially arranged plates. Arms may or may not bear pinnules. Crinoid stem plates exhibit various sizes, shapes and ornamentation (sometimes within the same specimen). Because the skeleton disaggregates easily upon death, columnals usually cannot be identified as to species or genera even though they are ubiquitous fossils in some basins.

3. This is a modern stalked crinoid obtained from 1400' depth in the Florida Straits using the Johnson Sea Link submersible. Although ubiquitous in the shallow epeiric seas in the geologic past, few stalked crinoids exist today, and none occur above 800' depth. Sketch this specimen and label, stem, calyx, arms, pinnules, columnals, and cirri.

4. Camerate crinoids were the dominant crinoids of the Paleozoic Era. Examine the five common camerate crinoid genera listed below. All are good index fossils for the periods of their occurrence.

Dizygocrinus (Miss.) - A monocyclic form. Note the prominent arm attachment sites. Sketch the calyx.

5. Examine the well-preserved crinoid specimens upstairs in the geology museum to gain an appreciation of the form of these animals.

Part II - SUBPHYLUM ASTEROZOA

6. Examine the sea stars and brittle stars. Pick a sea star to sketch and label arms. ambulacral grooves, mouth, anus, madreporite and (if present) tube feet.

Part III - SUBPHYLUM ECHINOZOA

The following terminology applies to echinoids:

corona	spines	tubercles
periproct	peristome	ocular plates
genital plates	apical system	madreporite
ambulacrum	interambulacrum	dorsal
ventral	Aristotle's Lantern	teeth
perignathic girdle	lunule	

A. **Regular echinoids**

7. Examine the regular echinoid specimens. Sketch a regular echinoid (you may use your dissection specimen) and label ambulacral plates, ambulacral pores (together they compose an ambulacrum), interambulacral areas and plates, periproct, oculogenital ring (ocular and genital plates), anus, madreporite, peristome and mouth.

8. Compare *Eucidaris tribuloides* with *Strongylocentrotus*. *Eucidaris* is related to *Miocidaris*, apparently the only echinoid genus that survived the Permo-Triassic extinction to give rise to the diverse assemblage displayed here. This is a primitive echinoid in that each individual plate supports a single large spine and no spines are present in the ambulacra. *Strongylocentrotus* belongs to a more "advanced" group of regular echinoids. Plate compounding has allowed for tubercles (and in life, spines) to be included in the ambulcra and for an increase in the number of tube feet in each ambulacra. What are the advantages to having more tube feet and spines in the

ambulacra? Examine *Echinometra.* This echinoid exhibits an adaptation to life in high-energy environments by expansion of the ambulacra at their adoral margin to accomodate more tube feet for grasping firmly on the substrate.

B. **Irregular echinoids**

9. Examine the internal partitions of the broken specimens of clypeasteroids. What do you think their function was? What habitat are these animals adapted for? Evidence?

10. Examine the sand dollars. Note the dense covering of small tubercles. How do these compare to those of *Eucidaris*? What can you infer about the function of spines in sand dollars? What was the funtion of the lunule?

11. How do the specimens of irregular echinoids generally differ from regulars?

Part IV - SUBPHYLUM HOMALOZOA

12. This group ranges from the Middle Cambrian - M. Devonian. There are four classes which together are often referred to as the "carpoids". This bizarre group of echinoiderms is asymmetrical, although in some a secondary bilateral symmetry developed. Among carpoids are forms that have been interpreted as ancestral chordates by the British paleontologist R. P. S. Jefferies. Other workers believe that the similarities to chordates (the "flatfish" form, a tail-like appendage, gill slit-like structures) are actually the products of remarkable evolutionary convergence. However, in this case the mode of life of carpoids was probably not at all fishlike! Benthic detritus and suspension feeding modes of life have been ascribed to carpoids by workers assigning them to the echinoderms. Specimens of these animals are quite rare. Take a moment to leaf through the Treatise. vol. S 1 (2) pp. S609-S614 for photos and illustrations of well-preserved specimens.

APPENDIX A: ECHINOID DISSECTION

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Phylum Echinodermata
Subphylum Echinozoa
Class Echinoidea
Strongylocentrotus -- the green sea urchin

Begin this dissection by examining the cleaned test of a regular sea urchin. **Please handle these delicate specimens with care.** The periproct area is located at the top of the test. Radiating downward from the periproct are the five ambulacral areas. They are bounded by a double row of pores on either side, through which the tube feet protruded. Each ambulacral area has two rows of alternating ambulacral plates lying between the tube foot pores. The interambulacral areas likewise consist of two rows of alternating plates, but the plates are much larger than those of the ambulacra. Note the tubercles on the plates, to which the spines were attached.

Around the periproct there is a circle of ten plates. Five large, genital plates form the margin of the periproct. These plates each bear a conspicuous opening, the genital pore. One of the genital plates is slightly larger than the others and is perforated over its entire surface. This is the madereporite, the entry point for water into the water vascular system. Between the genital plates there are smaller triangular plates which do not extend to the periproct. These are the ocular plates, and through a pore in each of them the terminal tentacles of the ambulacra project.

Now, look inside the peristomal edge of the test (the bottom opening). There you will see five pairs of projections at the ends of the ambulacra. These are the auricles and are the points of attachment for muscles which operate the jaw apparatus (the Aristotle's lantern).

Obtain a specimen of the green sea urchin, *Strongylocentrotus*, for study and dissection. In the center of the upper (aboral) surface there are four plates that surround the anus. These plates comprise the periproct. On the other side, the mouth is centrally located and is surrounded by a lip, within which is a circular ring of muscle, for adjusting the size of the mouth aperture. A membrane stretches between the lip and the edge of the calcareous test. This membrane, the peristome, is covered with cilia and is perforated by five pairs of large oral tube feet.

In the intrambulacral area of the outer edge of the peristome are five pairs of branching gills (fleshy and brown in color). Also on the peristome and dispersed over the entire test surface are numerous stalked pedicellariae, beaked structures which are used for defense, for capturing small prey, and for cleaning the body surface. Find good examples of pedicellariae.

Examine the spines. Note that those spines nearest the equator are longer than the ones located toward the poles. A given spine sits on a tubercle of the plate beneath it. Spines are attached to the tubercles by a ring of muscles plus the outer epidermal covering. The muscles are capable of holding the spine in a fixed position, or they may slowly move the spine in any direction. Pull a spine off, and examine the socket in its base and its general morphology.

Remove the spines around the equator of your specimen (by scraping with the scapel), and make an equatorial cut around the test, using the scissors. Before lifting away the top half, carefully separate the mesenteries that hold the intestine and loops of the stomach to the body wall. Try to find the stone canal, leading from the madreporite toward the oral region. Now cut the canal and the adjacent mesenteries, and then carefully lift away the top half of the test.

The complex jaw mechanism, known as Aristotle's lantern, is located in the center of the oral region and surrounding the end of the esophagus. Its function is to chew the urchin's food. Above the lantern, the esophagus enters the stomach (also tubular) which has an almost complete clockwise turn. The stomach bends and leads into the small intestine. Finally, the intestine leads to the anal opening.

If possible, locate the stone canal. It leads to the ring canal that surrounds the esophagus at the point where the latter emerges from Aristotle's lantern. The ring canal may be identified as a thin-walled, visually indistinct channel lying on the margin of the aperture of the lantern through which the esophagus passes. The five radial canals pass down through the lantern and emerge on the oral body wall of the test between the auricles. Almost immediately lateral to the canals the first tube feet can be seen branching from the radial canal. Use the microscope to see these structures.

Note the ampullae of the tube feet along the ambulacra. These connect to each tube foot from the radial canals, which explains the two rows of pores seen on each side of the ambulacra on the cleaned test. Isolate the Aristotle's lantern and examine its structure under the scope. This complex structure of muscles and bones requires a separate dissection for complete understanding of its mechanics.

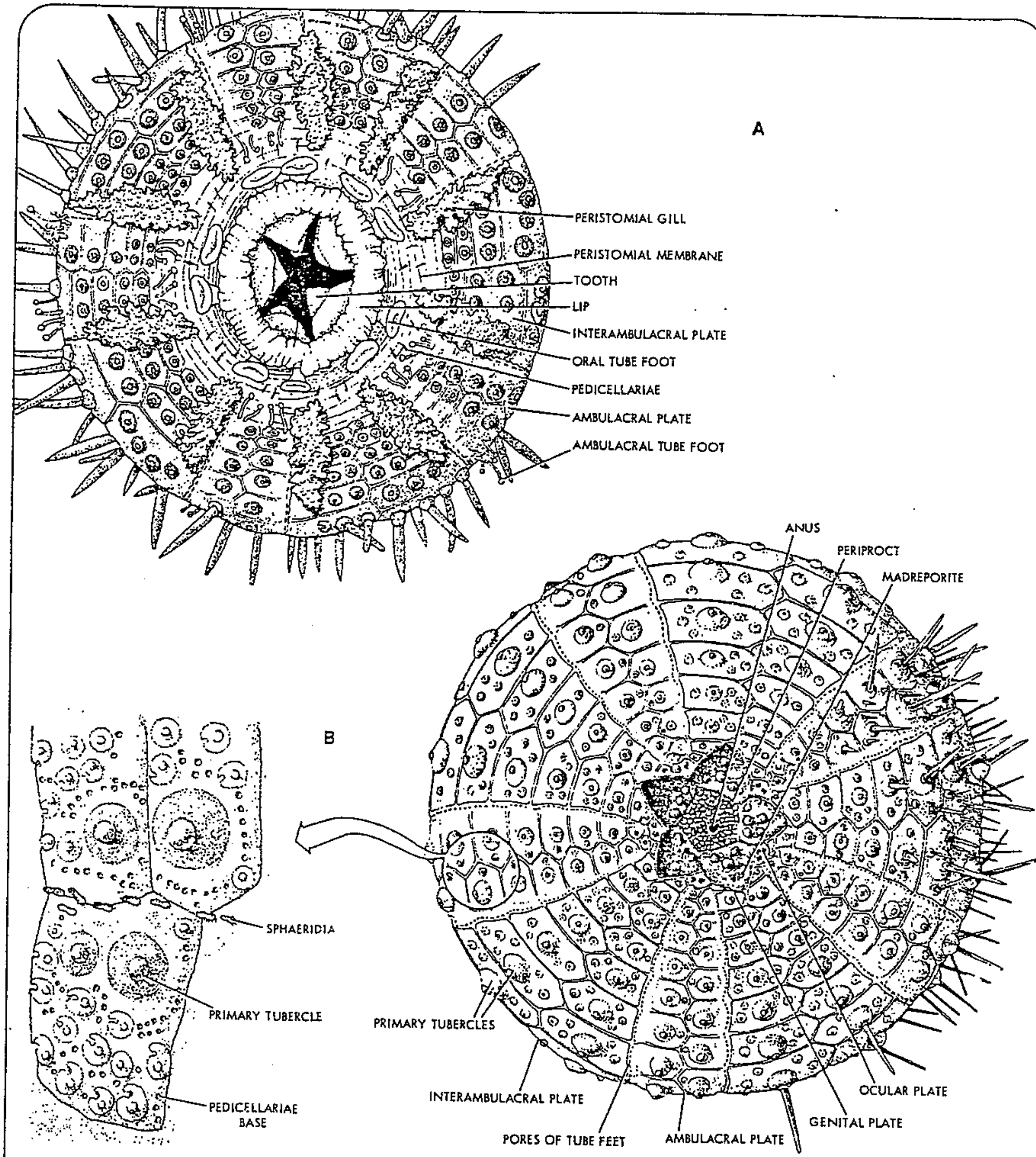

FIGURE 9.3 **A** ORAL SURFACE OF A SEA URCHIN. **B** ABORAL SURFACE OF A SEA URCHIN, CLEARED OF SPINES. THE CIRCLED AREA IS SHOWN IN GREATER MAGNIFICATION SO THAT THE LOCATION OF SPHAERIDIA CAN BE SEEN. **C** INTERNAL ANATOMY OF A SEA URCHIN: (i) DIAGRAMMATIC VERTICAL SECTION; (ii) ORAL AND ABORAL HALVES HAVE BEEN SEPARATED TO SHOW THE ARRANGEMENT OF THE ORGANS WITHIN THE TEST.

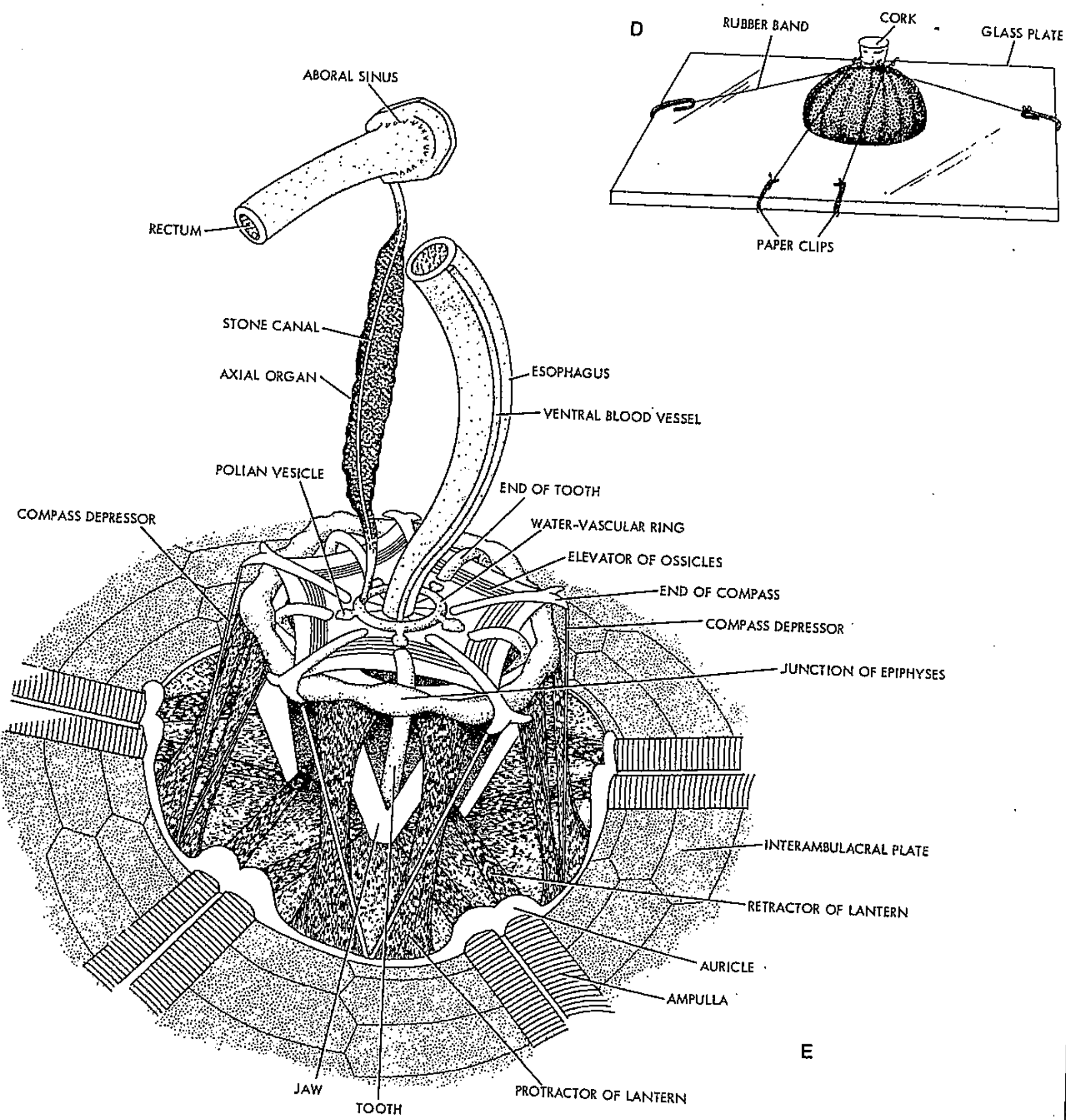

FIGURE 9.3 **D** DIAGRAM OF THE METHOD OF ANCHORING A SEA URCHIN TO A GLASS PLATE. **E** DIAGRAM SHOWING THE ORGANIZATION OF ARISTOTLE'S LANTERN IN A SEA URCHIN.