8.1 Introduction

Molluscs are important to paleontologists for several reasons. First, they have tremendous morphological diversity (only Phylum Arthropoda has more describe species). Second, molluscs usually possess well-calcified skeletons that have easily recognized features. Third, the phylum has exploited a wide variety of environments, from terrestrial forests, to freshwater lakes, down to the deepest part of the ocean. Finally, the molluscs have an excellent fossil record extending back to the earliest Cambrian. Although diverse in appearance, all molluscs share certain characters:

1. Their bodies are normally elongate and bilaterally symmetrical.

2. Most of the organs are contained by a body wall divided into a muscular lower part (the foot) used for locomotion or feeding, and an upper part (the mantle) which covers most of the body along with a free space (the mantle cavity).

3. Except for the bivalves, sensory structures are concentrated in a head (cephalization).

4. They all have a characteristic type of larval development.

Most molluscs secrete some type of CaCO$_3$ shell from the mantle; they utilize either aragonite or calcite, or a mixture of both.

8.2 Classification

Phylum Mollusca is divided into eight classes, all but one of which are extant today. Class Aplacophora forms no hard parts and has no fossil record, so we will ignore it. The other seven classes and their classifications will be discussed in detail separately.

8.2.1 Taxonomy

Phylum Mollusca (Cam-Rec)
  Class Monoplacophora (Cam-Rec)
  Class Polyplacophora (Cam-Rec)
  Class Scaphopoda (Ord-Rec)
  Class Bivalvia (Cam-Rec)
    Subclass Pteriromorpha
    Subclass Palaeoheterodonta
    Subclass Heterodonta
  Class Rostroconchia (Cam-Rec)
  Class Gastropoda (Cam-Rec)
    Subclass Prosobranchia
      Order Archaeogastropoda
      Order Mesogastropoda
      Order Neogastropoda
    Subclass Opistobranchia
    Subclass Pulmonata
Phylum **Mollusca:** Cambrian-Recent.

**Class Monoplacophora:**
Cambrian-Recent. Generally possesses a univalved, cap-shaped shell with little or no spiraling; soft parts show some segmentation.

**Class Polyplacophora:**
Cambrian-Recent. Usually possesses a shell formed of eight overlapping valves; foot is broad; head reduced.

**Class Scaphopoda:**
Ordovician-Recent. Shell tubular, expanded at one end and open at both; foot conical; no gills present.

**Class Bivalvia (Pelecypoda):**
Cambrian-Recent. Shell usually of two valves hinged dorsally; foot generally hatchet-shaped; head lacking.

**Class Rostroconchia:**
Cambrian-Recent. Shell consists of two equal valves joined in adults by an enclosed hinge; the posterior of the shell is usually produced into an elongate tube.

**Class Gastropoda:**
Cambrian-Recent. Generally a spirally-coiled shell, body usually asymmetrical, with a distinct head, pair of eyes, and one or two pairs of tentacles; foot is broad.

**Class Cephalopoda:**
Cambrian-Recent. Large head with well-developed eyes, horny (chitinous) jaws, and many tentacles; head fused to foot; shell (when present) external or internal.
Figure 8.1 Radiation of the mollusks from the “hypothetical ancestral mollusk” (modified from Clarkson, 1993: Prothero, 1998).
8.3 Class Polyplacophora

Polyplacophorans, or chitons, are marine molluscs common in intertidal areas today. They have also been found at depths down to 5,000 meters, but they are most prevalent on rocks and seaweed in the intertidal zone.

Chitons are generally ovate in outline and have a greatest thickness of about one-fourth their greatest width. The body is bilaterally symmetrical, with a head visible only from the ventral side. A band of muscular tissue, the girdle, runs along the dorsal periphery of the animal. Their girdle commonly has embedded in it small calcareous spines, scales or spicules.

The chiton shell normally consists of eight, articulating calcareous valves with the joints between them running perpendicular to the axis of the body. These valves are constructed in such a way that the animal can often roll up like a pill bug (isopod; Phylum Arthropoda) when disturbed. The surface of the valves is usually smooth, but can be ornamented by ribs, knobs or thin lines.

Fossil chiton specimens are almost always loose, disarticulated valves. The lobed nature of the intermediate pieces gives them the common name “angel wings” or butterfly shells. They have been found in rocks of the Cambrian and every succeeding period, but are rare.

Figure 8.2 Tonicella, the lined chiton (class Polyplacophora, order Ischnochitonida). (from Brusca, 1990)

8.4 Class Scaphopoda

Scaphopods are semi-infaunal, marine animals and are fairly common today in nearshore and bathyal environments. Their shells are never abundant in the fossil record, except for occasional local concentrations in Cenozoic deposits.

The shell of a modern scaphopod is a tapering tube, open at both ends, with a greatest diameter of little more than 6mm, and a length usually no greater than 8cm. Because of the position of the mouth, the large end of the shell is anterior, and the small end posterior. The exterior has finely spaced growth lines and usually some type of longitudinal ornamentation. Often the small end has an indented terminal pipe.

Scaphopod soft parts consist of a poorly-defined head, a conical foot, a visceral mass, and the standard molluscan mantle. There are no gills—respiration is accomplished by direct exchange with tissue. The animal feeds by capturing small prey (usually foraminifers) and deposited particles with small tentacles attached to the head. This food is passed to the mouth and is processed by a radula.

Figure 8.3 An example of scaphopod shell morphology and diversity. Left: Cadulus, Right: Dentalium; from Boardman, et al, 1987)
8.5 Class Bivalvia

The bivalves are characterized by a two-valved shell that protects the soft body completely. These valves are joined by a hinge on the dorsal side of the animal along a line parallel to the length of the body. Thus, unlike brachiopods, one valve is on the right side of the animal, and the other on the left.

All bivalves are aquatic, with the majority living in shallow marine waters. Most are benthic and quite sluggish, although a few (notably the common scallops, Family Pectinidae) can swim through the water for short distances by clapping the valves powerfully. Many bivalves burrow into various substrata, from sand and mud to wood and rock (see Appendix A). Another common life habit among the class is attachment to the sea bottom, or some type of hard substrate (shells, rocks, piers, wharves, boat hulls, etc.).

Figure 8.3 Bivalve morphology based on a living *Cerastoderma*: (a) Internal features of the right valve. (b) External features of the left valve. (c) Reconstruction of the internal structures attached to the right valve. (Benton and Harper, 1997)

The bivalve body consists mostly of a muscular foot in the anterior, and a series of gills (*ctenidia*) amid a pair of siphons (if present) in the center and posterior. The viscera include, from front
to back a **mouth, stomach, intestines, kidney, anus,** and a **heart** near the **dorsal margin.** The enclosing mantle produces the hinged shell, which is usually closed by two **adductor muscles** (anterior and posterior). Bivalves have no diductor muscle system for opening the valves; instead they usually use an elastic **ligament** that automatically opens the shell when the adductors relax.

Bivalves have been divided in the past into five major groups, based primarily on the method of feeding. These ecological groups are important to the general evolutionary history of the class, and indeed to the history of most of the other benthic marine invertebrates. They are:

1. **Labial palp deposit feeders:** These clams burrow into the sediment to gather food particles with fleshy extensions of their labial palps. The **palaeotaxodont** nuculoids are the only bivalves that feed in this manner.

2. **Epifaunal suspension feeders:** This group of bivalves lives on top of the substrate (**epifaunal**) and uses ciliary action of the gills to direct food-bearing water currents through the mantle cavity.

3. **Infaunal suspension feeders:** These animals burrow into soft substrates or bore into rock or wood, usually until they are well below the substrate-water interface. Water is drawn into the mantle cavity through fleshy siphons by beating the gill cilia.

4. **Infaunal non-siphonate suspension feeders:** Most of these bivalves are burrowers, with a few anchored by byssal threads. All live close to the sediment-water interface and direct food-bearing water currents through the mantle cavity without the use of siphons.

5. **Infaunal mucus-tube suspension feeders:** Instead of having a fleshy siphon to channel incoming water currents, these clams use a tube of mucus constructed by the foot. Often they possess a single, posterior exhalant siphon. Only the **heterodont** lucinaceans feed in this manner.

![Figure 8.4 Substrate relations of some modern bivalves. (a)-(d) Surface dwelling, suspension-feeding bivalves: (a) Crassostrea, a cementer; (b) Pecten, a bivalve capable of short pulses of swimming; (c), (d) Pinctada (pearl oyster) and Mytilus (mussel), moored to the substrate by organic threads. (e)-(o) Bivalves living within rock or sediment substrates: (e) Pholas, a rock-borer; (f) Hiatella, a rock nestler; (g), (h) Nucula and Yoldia, shallow-burrowing deposit feeders; (i) Atrina, a semiinfaunal bivalve; (l) Mya, a relatively deep infaunal suspension feeder: (m) Mercenaria, a shallow infaunal suspension feeder; (n) Tellina, infaunal deposit feeder: and (o) Cuspidaria, an infaunal carnivore. (Valentine, 1973, after Stanley, 1968; from Newton and Leporte, 1989)
During the early Paleozoic, epifaunal and primitive infaunal siphonate suspension feeding was the most common bivalve life mode. Infaunal siphon feeders appeared in the middle and late Paleozoic, but they gained prominence after the Permo-Triassic extinctions. The infaunal and epifaunal forms increased in diversity throughout the Mesozoic until the Cretaceous-Tertiary extinction event, when the epifaunal suspension feeders were decimated. During the Cenozoic, the infaunal siphonate clams continued to diversify. The labial palp deposit feeders and the mucus-tube builders evolved early in the Paleozoic and remained relatively unaffected by the extinctions and diversifications of the remainder of the class.

8.5.1 Classification

Many diverse schemes have been developed for the classification of bivalves, but in paleontology we use one based on shell morphology. The Treatise on Invertebrate Paleontology employs a system based on general shell shape, microstructures and hinge configuration. These features generally correlate to the various life modes.

A glance at the classification outline will show you that the taxonomy of bivalves is complicated. Remember that you will not be required to identify all the groups listed or classify below the class level.

Subclass Palaeotaxodonta
The palaeotaxodonta are the simplest and most primitive of the bivalves. They have an equi-valved shell and taxodont dentition (numerous approximately equal, undifferentiated hinge teeth). These include the labial palp-feeding nuculoids, which are small clams found today in deep water and fine sediment.

Subclass Pteriomorpha
All the pteriomorphs are byssate or cemented as adults, and most have auricles of some sort at the hinge margin, but convergence and parallelism have made the determination of more definitive shell characters impossible. Important pteriomorphs include the arcoids, mytiloids, pectinaceans, ostreaceans, and inoceramids.

Subclass Palaeoheterodonta
These were the first bivalves to appear in the fossil record, palaeoheterodonts are known from certain Cambrian rocks. They are equi-valved and usually have only a few hinge teeth. The important palaeoheterodonta include the unionaceans (freshwater clams), and trigonoids.

Subclass Heterodonta
The heterodonts include most of the common clams. Their hinge teeth are differentiated into vertical cardinals below the beak (umbo) and sub-horizontal laterals on either side. Most are infaunal siphon feeders (the most notable exception being the mucus-tube building lucinaceans). Included in the heterodonts are the lucinaceans, carditaceans, crassatellaceans, rudistaceans and veneraceans.

8.6 Class Rostroconchia

Rostroconchs are “bivalved” fossils belonging to the only known extinct class of molluscs. A rostroconch resembles a clam superficially, but the shell has no ligament or articulating system at the “hinge”; in fact, layers of calcite extend across this region, so that the hard part of a rostroconch appears much like a taco shell. The rostroconch shell apparently broke periodically at the margin to permit shell growth. The posterior of the shell is usually elongated into a flattened tube. To date, 34 genera have been described. Rostroconchs are usually rather small, often less than two centimeters in length. Some large forms (about 15cm long) can be found in Devonian limestones of the midcontinental United States.
Most invertebrate paleontology textbooks classify rostroconchs as members of Bivalvia, but the consensus among paleontologists today is that they are sufficiently different enough to rank as their own class of molluscs. It appears that the rostroconchs are the ancestral stock from which the bivalves and scaphopods evolved, making the rostroconchs a paraphyletic clade.

Figure 8.5 Advanced Rostroconch morphology. Left: Pseudocononocardium, Middle: Eopteria, Right: Arceodomus (from Boardman et al, 1987)

8.7 Class Gastropoda

Gastropods, or snails, are a group of invertebrates familiar to everyone. They are well known in part for their ability to occupy and hold tenaciously to a diversity of living environments, from the sediments of the deep sea to the lettuce heads in our own gardens.

In spite of the wide assortment of life modes among the gastropods, they have a rather simple body plan. Most have a shell, spirally-coiled to some degree, that covers the main organs of the body. The muscular foot forms a base for the typical snail, and is the animal’s principal means of locomotion. Many gastropods have tentacles and eyes in the head region, along with some sort of feeding apparatus. Respiration is usually accomplished with a feather-like gill (ctendium) that extends into the mantle cavity at the anterior of the body. In some gastropods the mantle cavity is posterior, along with the gill. A few terrestrial snails lack gills, having instead either an air-breathing “lung” formed from the mantle cavity, or a mantle surface modified for respiration.

Most snails have an unusual feeding mechanism just inside the mouth that has been used in the classification of living forms. This device, termed the radula, is a long belt of tough, flexible material with rows of minute teeth. It is usually used like a strip of rasping sandpaper to scrape food from a surface or to bore into other shells. Some snails have radulae modified into poisoned darts for immobilizing or killing prey.

Another important feature found in snails is the operculum. The gastropod operculum is a plate-like structure that is attached to the end of the animal’s foot. It protects the animal by acting like a door to the shell’s opening (aperture). Once the snail is safely inside its shell, the operculum blocks the opening and protects the snail in times of stress (e.g. storms or predation).

No general discussion of the Gastropoda is complete unless the process of torsion is mentioned. While in the larval stage, snails twist the viscera in a counterclockwise direction to bring the anus above the head. Ancient snails probably did not undergo torsion, and some advanced forms have reversed the effects secondarily.

Paleontologists of course deal almost exclusively with the shells of snails. Unfortunately, the snail shell often reflects very little of the critical soft-part anatomy. Classification then, of extinct gastropods involve considerable inference.

Most snail shells can be thought of as elongate cones wound into a spiral by varying degrees. Those shells that are planispiral are coiled symmetrically in a single plane. Pseudoplanispiral is a condition where the shell is coiled in a plane, but cannot be divided into symmetrical halves by this plane. Conispiral shells are coiled along an erect cone. Most conispiral shells are coiled clockwise (dextral)
down the cone, but a few are coiled in the counterclockwise direction (sinistral). The fundamental patterns form the basis of a variety of shell types.

### 8.7.1 Classification

Since the characteristic features of gastropods are primarily soft anatomical characters, paleontological classification is difficult. In this lab you will be expected to recognize only certain distinctive groups.

Gastropods have been placed in three subclasses: the **Prosobranchia** (“forward gills”), the **Opistobranchia** (“backward gills”), and the **Pulmonata** (“lung bearers”). All three are abundant in the fossil record, but the first is by far the most common.

**Subclass Opistobranchia**

The opistobranchs are exclusively marine, rather small snails with a minor fossil record. There is a general trend in the group toward a reduction and internalization of the shell. Pteropods are very small, nektic opistobranchs found in the plankton. They have a thin shell and an impressive, bilaterally symmetrical “winged” foot that enables them to swim. Pteropods are useful warm-water indicators in some Quaternary deep sea sediments, but they are rare as fossils prior to that time.

**Subclass Pulmonata**

The pulmonate gastropods include over 7,800 species in about 50 families, but in this lab we will see very few. Pulmonates are mostly terrestrial and freshwater dwellers, so they appear sporadically in the marine record. These snails are useful for correlating nonmarine sequences with marine deposits. Separation of the pulmonates from the prosobranchs using only shell morphology is truly a job for experts!

**Subclass Prosobranchia**

The prosobranchs are divided into three orders, which we will spend most of our time with (figures are from McKinney, 1991; Prothero 1998)

1. **Order Archaeogastropoda.** These were the dominant gastropods in the Paleozoic, and are thought to be the most “primitive” of the snails. It is an extremely diverse order with only one general shell characteristic is that they lack anterior canals.
2. **Order Mesogastropoda.** The mesogastropods have a range in form even broader than that of the archaeogastropods. They may look very similar to the previous order—almost identical in a few cases—and they sometimes possess an anterior canal resembling that of the third prosobranch order (the neogastropods). Again, the critical taxonomic features are in the soft anatomy.

3. **Order Neogastropoda.** These are the dominant snails of the Cenozoic and today. All are carnivorous to some extent, and a large number are active predators. All neogastropods have some sort of anterior canal, and many also have a posterior canal or notch.

### 8.8 Class Cephalopoda

The cephalopods are a group of molluscs quite different from the rest of the phylum. Along with the standard molluscan body plan, they have a large well developed head, with large well developed eyes, and a set of prehensile arms that usually bear rows of suction cups. Included in this class are the squids, octopuses, and chambered nautiluses. Instead of being sessile or at best sluggish like the other mollusces, cephalopods are quick movers, swimming through the water or crawling over the substrate. They also have a variety of advanced defense mechanisms, such as camouflaging ability or ink clouds.

Those cephalopods that bear hard parts are, of course, the most interesting to paleontologists. The shell of the *Nautilus*, and some related but extinct forms, is a **planispiral**, mostly involute, coiled calcium carbonate cone divided by calcareous walls (**septa**) into chambers. In the living *Nautilus* these chambers contain various gases. A narrow tube, termed the **siphuncle**, extends from the final chamber back through the septa to the initial chamber. This tube consists of living tissue and is thought to function as a regulator of the gas composition in the chambers (hence the buoyancy of the animal). As the animal grows, it builds successive new septa of increasingly larger size, a larger **living chamber**, and a longer siphuncle for communication with the rest of the shell. As in all molluscs, the calcareous parts are built by the mantle tissue enveloping the body.

Shell-building cephalopods are known from the Cambrian to the present. They are very important to biostratigraphers, especially those working with Mesozoic rocks, so there is at least a utilitarian classification. We will discuss in detail those fossil cephalopods important to paleontology.
8.8.1 Order Nautiloidea

Several cephalopods that seem only distantly related have been included in this group, so there is considerable diversity in form. Nautiloids appeared first in the Cambrian as straight, conic shells with the siphuncle running down the center of the septa. Where the siphuncle pierced a septum, the wall turned along it, forming a septal neck that in nautiloids usually points posteriorly.

Later nautiloids began to coil the tube in a variety of ways. The siphuncle remained central in location, and the suture pattern (the system of lines formed where the septa meet the interior of the shell wall) is simple (usually a set of sinusoidal curves).

The first nautiloids were probably grazers on algal mats of the Silurian and Ordovician. Gradually, they seem to have adopted a more carnivorous habit—probably feeding on arthropods, worms and other molluscs.

Nautiloids were the most important cephalopods of the early and middle Paleozoic. They experienced a few episodes of diversification and extinction throughout their history, but have generally been declining in numbers and species since the Ordovician. One genus, *Nautilus*, lives today.

![Figure 8.6 External morphology (left) and internal features (right) of the living *Nautilus* (from Ward, 1987; Prothero, 1998).](image)

8.8.2 Order Ammonoidea

These cephalopods arose in the Devonian directly from the nautiloids through an intermediate stock similar to the straight-shelled bactrid nautiloids. They are usually coiled to some extent. The siphuncle of an ammonoid is usually located along the margin of the shell, not in the center like the nautiloids. Also, the septa are folded intricately, forming more complicated suture patterns than those of the nautiloids.
Ammonoid suture patterns, which have diagnostic value, are of three basic types (figures from Benton and Harper, 1997):

1. **Goniatic-siple** first-order lobes and saddles. This type of suture is common in cephalopods from the late Devonian to the Permian, occurring rarely in Triassic forms.

2. **Ceratitic-lobes** divided into second-order lobes and saddles. This type of suture first appeared in the Early Mississippian and occurs in some Pennsylvanian and Permian forms, but is the predominant pattern in Triassic forms and occurs in a few Cretaceous species as well.

3. **Ammonitic-lobes** and saddles divided into second-order and sometimes third-order lobes and saddles. This type of sutures ranges in age from Permian to Cretaceous, but is particularly characteristics of Jurassic and Cretaceous species.
Some ammonoids had a pair of calcareous chitinous plates, termed aptychi. Their function is debated, but they may have closed the shell, like the gastropod operculum. In some Mesozoic rocks, they are more common than the ammonoid shells themselves.

Ammonoids had a complex history; they began to diversify gradually in the Devonian, but met near extinction at the close of the Permian. In the Mesozoic though, they flowered into hundreds of species with a wide array of shell types. At the close of the Cretaceous the entire group went extinct.

**Subclass Coleoidea**

Several cephalopod groups, joined in the subclass Coleoidea, built only internal shells or had no shells at all.

1. **Order Teuthida.** These are the true squids, which have a fossil record beginning in the Jurassic. They are elongate animals with ten arms and a chitinous shell, termed the pen, lying above the visceral mass. Squid fossils consist of the pens and a few rare impressions of the soft parts.

2. **Order Belemnitidia.** These extinct animals resemble the squids in having cylindrical bodies with a head and a set of anterior arms. However, they possess heavy internal shells that look more like .50 caliber bullets than anything else. Well preserved belemnite shells have a chambered area called the phragmocone, a rudimentary siphuncle, and a massive rostrum that apparently acted as a counterweight. Belemnites have been found in rocks as old as Mississippian, but are most common in the middle and late Mesozoic deposits. They appeared to have died out at the end of the Cretaceous, but one very questionable Eocene form is known.

3. **Order Sepiida.** Sepiids include the living cuttlefish. Most are flattened dorso-ventrally and have ten arms and eyes similar to a squid. They usually live on the sea bottom and capture animals for food. Like the squids, sepids can discharge clouds of ink to confuse pursuers. *Spirula* is a sepiid that drifts through the waters of the deep ocean. It is not dorso-ventrally flattened like most other sepids, and it has an internal shell with chambers.

4. **Order Octopodida.** The octopuses have a very scant fossil record, mainly, of course because they rarely produce hard parts. An impression from the Upper Cretaceous is the earliest known fossil of the group. Octopuses have eight arms (hence the name) and a bulbous body. The female of the genus *Argonauta* secretes a small shell to transport its eggs safely; this shell resembles some Mesozoic ammonoid shells superficially, but differs in having no septa or siphuncle.
8.9 Terminology

siphon  foot  gills (ctenidia)
adductor  isomyarian  anisomyarian
monomyarian  ligament  byssus
nacre  periostracum  myostracum
muscle scar  pallial line  pallial sinus
gape  byssal notch  ribs
lunule  escutcheon  hinge
dentition  taxodont  foot
torsion  radula  spire
whorl  siphon  protoconch
apical angle  umbilicus  columella
aperture  dextral  sinistral
operculum  planispiral  conispiral
arms  tentacles  mantle cavity
jaws  siphuncle  septum
living chamber  phragmocone  ectocochlear
endocochlear  orthoconic  heteromorph
rostrum  camerae  suture
saddle and lobe  goniatite  ceratite
ammonite

8.10 Questions

8.10.1 Bivalvia

1. Why are the valves of dead clams often gaping or separated? Think about the way the muscle/ligament system works.

2. Look at the recently deceased *Pecten* (Subclass Pteriomorpha, Order Pteroida) and its fossil counterpart. What information is lost in the fossil scallop? Think about the stability of shell materials.

3. Look at *Tivela* (Pismo clam) or some other venerid clam. Sketch and label the following features: teeth, hinge, umbo, muscle scars, anterior/posterior, pallial line, and pallial sinus. Are these bivalves epifaunal or infaunal? How can you tell?
4. *Exogyra* and *Gryphaea* were oysters common in the Jurassic and Cretaceous. Based on their morphology, do you think they were epifaunal or infaunal, attached or free-living?

8.10.2 Gastropoda

1. How were these gastropods preserved? Why do you think that this is a common mode of preservation for gastropods?

2. What is the function of the small plates with these specimens? How could you recognize these plates as gastropod parts if the shell was not also found?

3. What do these structures (drill holes) indicate about the feeding habit of some gastropods?

8.10.3 Cephalopoda

1. *Nautilus* is the last living representative of the Nautiloidea. What was the function of the shell? How is it oriented in life?

2. Many lower Paleozoic nautiloid shells were straight (orthoconic) or slightly curved (cyrtoconic). If the chamber (camera) were gas-filled as they are in *Nautilus*, what was the life orientation of these animals?

3. How can we be certain these unusual forms (heteromorphs) were ammonites? What information would you look for to differentiate cephalopods from gastropods?

4. Belemnites such as these were abundant during the Mesozoic. Do these specimens constitute an internal or external skeleton? Is this the entire skeletal structure?
Bivalve mollusk anatomy

1. Use disposable rubber gloves during the dissection
2. Work with a partner

Carefully dissect the specimen of the clam, and be sure to locate the following soft parts: (ask your TA to confirm your identifications)

Soft part anatomy
Adductor muscles
Mantle
Siphons
Gills
Visceral mass
Foot
Ligament

Now, remove all the soft tissues from one valve (shell) and examine only the hard parts

Hard part anatomy
Right valve
Left valve
Beak (also called umbo)
Ligament groove
Hinge teeth and sockets
Muscle scars
Pallial line
Pallial sinus
Growth lines

Which soft parts leave an impression on the hard parts?

Which soft parts don’t leave an impression on the hard parts?

(for more information on the integration of hard & soft parts in burrowing clams, see Appendix A)
Relative growth

You and your partner have a bag of approximately 10 clam shells to measure. Measure the length and width of each specimen and, using the graph paper provided, make a plot showing their relative growth.

Is the relative growth of length and width isometric or allometric? Explain your answer.

Absolute growth

One or more of the specimens may show growth lines on the exterior of the shell. Assuming that these lines represent winter hibernation (and cessation of growth), make a graph that plots age (in years) vs length.

Is the growth rate of this clam constant through life or does it change as the clam gets older?
Appendix A

Functional integration of hard parts and soft parts in burrowing bivalves

1. Anatomy of bivalves
   - **foot**- used for locomotion/to penetrate sediment
   - **adductor muscles**- work to close shell
   - **ligament**- elastic tissue opens shell
   - **pedal retractor muscles**- pull foot back inside shell

2. Shape in burrowing bivalves
   ranges from elongate to equidimensional

3. The burrowing cycle in bivalves
   i. Adductors relax, valves tend to open, forming a shell anchor in the sediment
   ii. Blood is injected into the foot, and the foot probes the sediment
   iii. Adductor muscles contract
      - water ejected from mantle cavity, loosening the sediment
      - foot is compressed, forming a foot anchor in the sediment
      and pedal retractor muscles try to pull foot back into shell, actually serving to pull the shell down towards the foot.
      ---First one pedal retractor, then the other.
      In equidimensional bivalves, this results in a rotary, rocking motion.
      In elongate bivalves, both muscles pull along the same line, resulting in a slicing motion.

The cycle repeats itself several times….

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**Figure 8.8**: Burrowing of a bivalve mollusk. (i) The shell gapes and forms an anchor during penetration of the foot (ii), (iii) The tip of the foot is dilated while the shell is drawn down into the sand (after Trueman, 1975)