Biology 337 *NAME:* __________________________ **Lab worksheet**
Biology of Invertebrates *LAB TIME:* ______________________ **Dr. Bob Podolsky**

LAB E. Ph. MOLLUSCA (Cl. Polyplacophora, Cl. Gastropoda)

Molluscs are so extraordinarily diverse in body design that we take two labs to cover only four of the seven classes. The classes are united by common body plan features, but these features have been modified for different lifestyles in diverse habitats. Start with our lecture figure of a **generalized mollusc**, recalling that the soft, unsegmented body generally includes a **head** region, a large ventral **foot**, a **visceral mass** that contains the body organs, and a **mantle** (a specialized epithelial tissue that covers the visceral mass). A fold of mantle above the foot creates the **mantle cavity**, an <u>external</u> space that typically houses molluscan gills (**ctenidia**) as well as several pores that lead from internal organs (the **anus**, **excretory pores**, and **gonopores**). In taxa with internal fertilization like snails, tissue in the mantle cavity of males can be curled up into a tubular **penis**. In addition, most molluscs (with the exception of bivalves) use a belt of chitinous teeth (the **radula**) just inside the mouth for feeding. Many molluscs also have an external **shell**, secreted by the mantle. A few taxa have internalized or entirely lost the shell.

Today you will examine two versions of the mollusc body plan, **Cl. Polyplacophora** (chitons) and **Cl. Gastropoda**. Recall that gastropods account for about 4/5 of all mollusc species. Each class also includes variations on its own class-level body plan.

CLASS POLYPLACOPHORA (="many plates")

The **chitons** (the common name for all members of this class) have a highly conserved body plan. All members have a shell composed of 8 articulated **plates**, or valves, embedded in the dorsal mantle; the mantle grows up and around the edges of the plates, creating a fleshy flap called the **girdle**. All members have the same basic external features, including a large number of ctenidia housed in a mantle cavity that goes around the foot, and all have the same basic internal anatomy. In fact, all chitons are **marine**, and only a single taxonomic order is recognized. Differences occur in body size, shape, color, girdle ornamentation, and the degree to which the plates are covered by mantle tissue.

- <u>Shell composition and structure</u>. Examine the prepared slide of a mollusc shell in cross section. (This is a clam shell but reflects general mollusc shell properties.) Identify and sketch the thin brown outer **periostracum** composed of the protein **conchiolin**; next a **prismatic layer** of elongate calcium carbonate crystals, held together by a conchiolin matrix; and finally an inner **nacreous layer** laid down as a set of flat sheets. This layer, called "mother of pearl," was harvested for the manufacture of buttons until plastic was used. Nacreous construction also forms a true **pearl**, which the animal creates around an irritant that lodges between the mantle and nacreous layer.

- <u>Plates</u>. Examine the dried chiton from which most of the soft tissue has been removed. Note how the articulations between plates allow chitons to adjust their bodies to the contours of the substrate to which they attach. If dislodged from the substrate, many chitons will protect the soft tissue below the plates by rolling up like a pillbug. Chitons have lensed photoreceptors (**shell eyes**) located throughout the valves. If free valves are available, examine one under a dissecting microscope with transmitted light to look for shell eyes (small dark pits on the surface).

TQ: Shell eyes (also called "aesthetes") are unique to chitons. Explain briefly how the positioning of their eyes relates to other aspects of how the body is designed. Do the same evaluation for the position of eyes in snails and scallops (ask if you don't know where these are).

- Dorsum. Examine the dorsal surface of several preserved chitons. Note how the mantle tissue known as the **girdle** grows around the edges of plates to different degrees in different species. Two species from the Pacific Northwest illustrate this well: *Katherina tunicata* has plates that are partially overgrown by mantle, while in the gumboot chiton *Cryptochiton stelleri*, the world's largest species, the mantle has completely overgrown and fused over the plates.

TQ: The $CaCO_3$ plates of *Cryptochiton*, like certain other molluscs, are said to have become "internalized," leading to an unusual arrangement of tissues above and below the shells. What is the embryonic origin of those two tissues above and below the plates?

- Ventrum. In a preserved specimen, make sure you can distinguish among the divisions of the ventral surface into the **girdle**, **head**, and **foot.** The distinction between foot and girdle is made easier in a specimen where the girdle is pulled away from the foot to reveal the **mantle cavity** along each side of the foot. The head is most easily distinguished by the small **mouth** at its center, virtually the only visible feature. Chitons typically scrape algae off rocks using a **radula** that, in some groups, is made of the extremely hard, iron-bearing salt **magnetite.** (When dissected out, the radula can actually be picked up by a magnet.) You might be able to see the radula through the open mouth on a dissecting scope.

As you peer into the mantle cavity on a dissecting scope, you will see a series of simple **ctenidia.** Different chiton species have from 6 to 88 pairs of ctenidia hanging down, from the roof, into the mantle cavity. The foot is used to creep slowly along surfaces and, when disturbed, to attach firmly to the substrate like a suction cup.

TQ: Explain briefly which muscles would be used for these two activities: **creeping locomotion** (both **direct** and **retrograde** locomotion) and **firm attachment** by creation of a suction cup.

Quickly sketch the dorsum and ventrum, labeling the **head**, **mouth**, **foot**, **girdle**, **anus, mantle cavity**, and **ctenidia**. In the ventral view, sketch the expected **direction of water flow** through the mantle cavity, and describe on your sketch the mechanism used to generate these currents. Using a dissecting scope, you might be able to locate pores near the posterior end of the mantle cavity--the **genital** or **excretory pores**, as well as two bumps surrounding the anus that are the chemosensory **osphradia** (may not be visible on all specimens).

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- If living chitons are available (difficult to find in Charleston!), carmine suspension or milk can be used to study water flow through the pallial grooves. Let the chiton attach to a glass slide, then invert the slide over some supporting small dishes in a larger dish of clean seawater. Squirt carmine suspension near the anterior end of the animal. Where do the particles leave the pallial grooves?

CLASS GASTROPODA (="stomach-foot")

Despite their enormous diversity, all gastropods share an important derived character: they all undergo torsion during development. Before reviewing the taxonomy and examining diversity in detail, make sure you can distinguish between **torsion** (all gastropods) and **coiling** (which occurs only in certain gastropods, as well as in some other mollusc classes).

→ ***TORSION*** involves a *dramatic twisting of the visceral mass* 180° counter-clockwise relative to the head and foot, which repositions the "posterior" mantle cavity above the head. This **developmental process** must have evolved before the common ancestor to current-day gastropods, because the character is shared by all members of the class. Members of two gastropod subclasses (**Opisthobranchia** and **Pulmonata**) secondarily undergo full or partial **detorsion** after the initial torsion event, which restores some (but not all) structures to the pre-torted position. For example, the nervous system usually retains traces of torsion in the way nerve cords are twisted in the body.

Because the anus discharges into the mantle cavity, a major consequence of torsion is the potential fouling of the head with wastes. Using different gastropod representatives, you will see a couple of different solutions to this problem, which all involve the use of cilia on ctenidia in the mantle cavity to generate water currents that move wastes past the anus and away from the head.

→ ***COILING*** involves the *growth of the entire body* in a spiral around a central axis, with each coil occurring around (or just below) the preceding coil. Remember that a gastropod literally grows out of the aperture of its shell, adding new material to the edge of the shell to accommodate the addition of body tissue. The process of coiling must therefore involve the differential growth of one edge of the body & shell relative to other edges. You will be asked later in this lab to speculate on how different body/shell growth patterns can occur.

Balancing the coiled shell with its viscera on the body has resulted in the shell being carried obliquely. This position restricts the size of the mantle cavity on the right side of the body, which has resulted in reduced size or loss of the right gill, kidney, and atrium of the heart (which receives blood from the right gill) in most coiled species.

Taxonomy. Relationships among gastropods, and molluscs more generally, are in revision. To organize the lab we will use traditional taxonomic categories. It is possible that some taxa that we will treat as *clades* may turn out to represent *grades*.

Subclass Prosobranchia—The largest group of marine and freshwater snails. The name ("forward gill") reflects the complete torsion of most species, which places the paired (O. Archaeogastropoda) or single (other orders) ctenidia "forward" in the mantle cavity over the head. All are aquatic, though some can survive many hours out of water. Most have separate sexes (**dioecy**) though some are **hermaphroditic**. Important orders include the **archaeo-** (abalone, keyhole limpets), **patello**- (limpets), **meso**- (slipper shells, moon snails), and **neo-gastropods** (whelks, conchs).

Subclass Opisthobranchia—All marine. Members of this subclass are diverse and generally slug-like, although several orders retain shells. Most are hermaphroditic and carnivorous. Opisthobranchs undergo torsion, followed by detorsion, restoring the anus to a posterior position. Some have lost a mantle cavity and ctenidia during their evolution and have secondarily derived "gills" called **cerata** (hence the name opisthobranch, meaning "dorsal/posterior gill"). Important orders include the nudibranchs, cephalaspideans, anaspideans, and sacoglossans.

Subclass Pulmonata—This subclass is dominated by terrestrial snails and slugs, but also includes most of the freshwater snails and some marine snails. These animals have successfully invaded terrestrial habitats, in part, by enclosing the mantle cavity into a lung-like structure that opens to the environment via a muscular **pneumostome**. Most are hermaphroditic.

SUBCL. PROSOBRANCHIA

Archaeogastropods, including the keyhole limpet and abalone, show the most primitive solution to the sanitation problem created by torsion. By creating a hole in the shell above the mantle cavity, water currents created by cilia on the **pair of ctenidia** are drawn past the head and *then* past the anus before exiting through the shell opening.

1. *Keyhole limpet*. Examine the preserved specimen and shell. A single hole is found at the shell apex (recall that this is the oldest part of the shell). This hole begins as a slit early in development and is enlarged and resculpted by mantle tissue as the animal grows larger. The **anus** is positioned close to the hole, so that water currents generated by the pair of **ctenidia** within the mantle cavity carry wastes out the top of the shell.

2. *Abalone*. Investigate the inside of a shell. Notice the **scar** on the shell where the **pedal retractor muscle** attaches, as well as the row of **holes** in the shell where water currents in the mantle cavity exit the top of the shell after passing through the ctenidium. Now visually line up the shell with the soft tissue of the animal, so that the muscle scar matches lines up with the muscle the holes line up the **ctenidia**. The **anus** is posterior to the ctenidia, at the end of the mantle cavity, positioned where wastes will be carried out the holes by ctenidial water currents.

Which hole is the oldest, and which has formed most recently? Trace the series of holes back toward the oldest parts of the shell. Note how some of the holes associated with the body when the animal was a smaller size "filled in" as they were no longer used.

TQ: How do keyhole limpets and abalones grow larger? Make a simple sketch of each shell, including "growth rings" that show where new shell must have been added to old shell for the animal to grow larger. Include in your sketch the location of ctenidia underneath the shell and the pattern of water flow through the mantle cavity.

Mesogastropods. This group has a mixture of feeding habits, as described below.

1. *Littoraria irrorata*. The marsh periwinkle is extremely common in salt marshes. When the tide rises, they ascend the stalks of the marsh grass Spartina spp. until well above water level. They use the radula to scrape up diatoms and filamentous algae growing on the *Spartina*. If animals are present on the aquarium glass, watch them to see the rhythmic movement of the radula scraping at the glass. Also, look for whether the foot uses direct or retrograde waves for locomotion. Note how the right and left sides of the foot can be coordinated separately.

Remarkably, the radula is also used to puncture the plant tissue, causing plant fluids to leak out that promote the growth of fungus that the snail uses as a food source. In this sense, *Littoraria* is a farmer!—it manipulates the supply of resources used to grow its food source, and continually harvests its crop.

Radula. Although you won't have time to complete a full dissection, one or two groups should try to dissect out a radula from a living specimen. Take an animal anaesthetized in $MgCl_2$ and use a vise to crack open the shell. Keep track of the anterior end and, using a dissecting microscope, peel away the tissues of the mouth to find the long, belt-like set of teeth. Compare the size of the animal to the size of its radula.

TQ: Imagine that you have dissected out the radula. What two asymmetries between the anterior and posterior ends could you use to deduce which end is which?

2. *Neverita (=Polinices) duplicatus*. A second mesogastropod, the moon snail *Neverita*, is a predator that lives in soft-sediment habitats, where it moves below the sand surface to find its buried prey. It uses a radula with very different kinds of teeth to scrape a hole in the shell of their prey (typically a bivalve) that they find just under the surface. On display are shells of moon snails as well as the shells of some of their victims. Note that the 'drill hole' has a distinctive beveled shape that results from the shape of the radula. You will be amazed, the next time you are picking up shells at the beach, to notice how many have these distinctive holes—moon snails are major predators in certain soft-sediment communities.

>>>Use the dissecting microscope to compare the shape of the beveled drill holes formed by *Neverita* to the rough drill hole in the olive shell, made by either a whelk or by an octopus.
Live specimen. Examine a live individual of *Neverita* in a clean bowl without sand. If the animal has been left undisturbed, notice the enormous foot that the animal uses to move around

and to bury itself. If an animal is feeding on a prey item, watch it undisturbed. The animal will use the radula to rhythmically scrape a hole before inserting the mouthparts for feeding on the soft tissues inside. When students are finished observing the animals, they should be placed onto the sand and periodically checked for their progress in burrowing into the soft substrate.

3. *Crepidula fornicata*. An unusual mesogastropod is the slipper shell, *Crepidula*. Although most prosobranch gastropods are dioecious (separate sexes), *Crepidula* is a **protandrous hermaphrodite**—it turns from male to female under certain conditions, usually after reaching a critical size. Examine the stack of *Crepidula*, if available. The first larva to settle becomes female and emits a chemical pheromone that attracts larvae to settle on top. These new settlers first become **males**, but turn **hermaphrodite** and then **female** as they grow larger. It is common to find large copulation stacks, with females toward the bottom and males toward the top. Now you know the origin of the name.

TQ: Propose an advantage to being a male when small and toward the top of a stack and another advantage of becoming a female when larger and topped by other individuals.

TQ: In order to reserve their position, individuals do not usually leave the stack. What options are possible for *Crepidula* to derive nutrition without ever leaving the stack? Consider options available to other animals that are sessile.

<u>Path of respiratory currents</u>. Recall that the archaeogastropods (keyhole limpets and abalone) showed one solution to the sanitation problem created by torsion. Most gastropods, though, have a different solution: they have evolutionarily lost the ctentidium on the right side and retain only the single ctenidium on the left side. In these cases water sweeps across the mantle cavity from left to right, passing the anus on the right side just before it leaves the mantle cavity *laterally* rather than dorsally.

Crepidula is good for demonstrating water flow through the mantle cavity. As already described for limpets, water flow generated by cilia on the single ctenidium sweeps across the mantle cavity from left to right.

>>> If a detached, living *Crepidula* is available, rest it on its dorsal surface in a dish of clean seawater. Introduce carmine suspension carefully on the animal's <u>left</u> side. Can you see carmine move into the mantle cavity, over the head, and out the right side? Where is the ctenidium?

<u>Feeding</u>. In addition to its unusual sexual habits, another unusual characteristic of *Crepidula* is its ability to capture food particles using mucus on the gills and cilia (which is the case for most bivalves). In light of this information, re-evaluate your answer to the previous TQ.

Use the dissecting microscope to see if any carmine particles are captured. What path do the particles then follow?

Neogastropods are typically predatory carnivores. Many prey on other molluscs, using the radula to "drill" through the shells of prey. Examine the following three distinctive examples:

1. *Ilyanassa obsoleta.* The mud snail *Ilyanassa* is extremely common in intertidal mud. Snails follow the mucus trails of conspecifics by following their scents, resulting in large aggregations. Bring a specimen to your desk to examine it in detail in the following extended exercise.

Shell. Orient yourself to the outside of a shell. The animal extends its head and foot from the **aperture**, which is elongated anteriorly to form a **siphonal canal** or **notch**, from where the **siphon** extends. When the body is retracted, the aperture is blocked by the **operculum**, a thin disc composed of the protein **conchiolin**. This protein also forms the outer most shell layer, the **periostrocum**, and more generally holds together the $CaCO_3$ crystals of the nacreous layer.

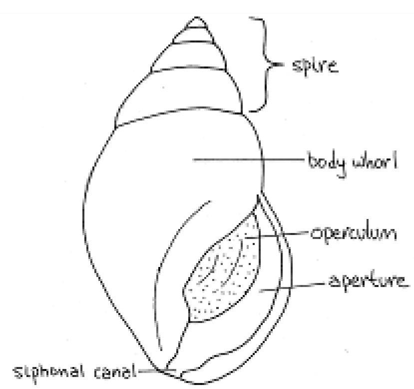
The shell is composed of a series of **whorls** around a central axis, the **columella**. Note that the largest whorl, the "body whorl" includes the aperture and contains the head, foot, and most of the visceral mass. Hold the shell so the aperture is facing you and the spire points up as in the figure. Is the aperture to the right (dextral) or the left (sinistral) of the central axis? Most gastropods are dextral, or right-handed, though you should look for exceptions.

Anterior. Examine your snail in water under a dissecting microscope. Wait for it to extend its foot and head, and observe the externally visible features of its anatomy as it crawls across the dish. The visceral mass remains inside the shell. The **head** bears a pair of conspicuous, sensory, **cephalic tentacles** and a dark **eye** lateral to the junction of each tentacle with the head.

Note the elephant trunk-like **siphon** emerging from the **siphonal canal** on the left side of the head. The siphon is a rolled up extension of the mantle edge, *not* a closed tube. The siphon is the *inhalant* canal that brings water into the mantle cavity past the **osphradium** (for chemo-reception) and **ctenidium** (for respiration). How is water motion across these structures created?

Look for the small **proboscis pore** on the anterior surface between the bases of the tentacles. The **proboscis**, with the **mouth** at its tip, is extended from this pore during feeding. *Ilyanassa* is a scavenger that feeds opportunistically on organic material left behind on the surface of mudflats.

Feeding. Make a "squid sandwich" by placing a small piece between two clean glass microscope slides, with the meat about 3 mm from the long edge of the slides. Place a rubber band around the opposite end of the sandwich to hold the two slides together, not so tightly that it squeezes out the squid. Lay the sandwich down in a bowl of seawater with a snail. Watch as the snail (1) "sniffs" the water with its siphon to locate the squid and then (2) inserts its proboscis between the two slides to feed. Using the dissecting scope, pay particular attention to the black **radula** which will be repeatedly exposed and withdrawn from the mouth at the tip of the proboscis.

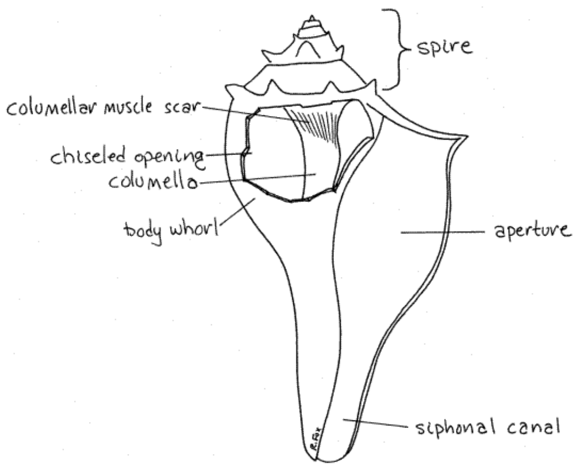


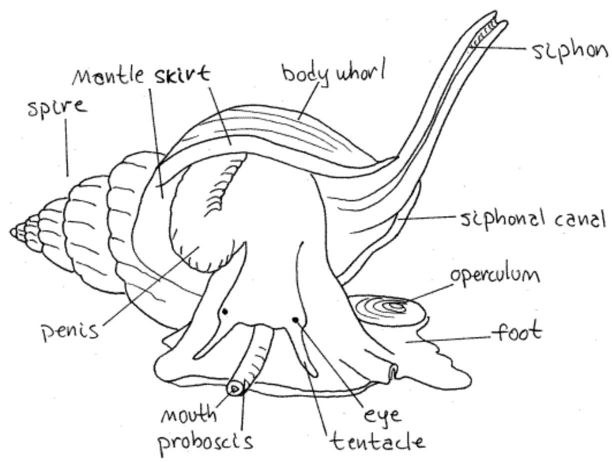
Operculum. Note the thin, flat, oval, **operculum** (composed of conchiolin) on the dorsal surface of the foot immediately posterior to the shell. The operculum functions as a door to close off the aperture. Poke the snail and watch it retract its head and foot, and then close the aperture with the operculum. Then place the snail in the dish with the aperture up and watch patiently as the head and foot emerge from the aperture. Watch the animal attempt to right itself with its foot.

2. *Urosalpinx cinerea*, the oyster drill (if available) is common along rock jetties and in oyster beds where it drills into oyster shells. Note the much larger **siphonal canal** that supports the siphon. As in *Ilyanassa*¸ it is used to direct water currents into the mantle cavity.

3. *Busycon carica*, the knobbed whelk, is a large bodied species that is common in shallow waters and sandy beaches of the east coast of the US. Like almost all snails it is dextral, although a closely related species (*B. contrarium*) is sinistral.

A cutaway shell may be available, showing a series of **whorls** around a central column, the **columella**. The last whorl, called the **body whorl**, is the largest and contains most of the live body. The smaller whorls stacked atop the body whorl, which form the **spire**, contain upper regions of visceral mass. If a live animal is present and active, some structures may be apparent, especially the **eye**, **tentacle**, **proboscis**, and **penis** on the right side of the head.





PAUSE to summarize in the table below some of the feeding modes you have observed among prosobranch gastropods (e.g., *Littoraria, Polinices, Crepidula, Ilyanassa, Urosalpinx, Busycon*).

Species	Order	Habitat	Feeding mode

- *Boonea*. Now, consider just one more unusual feeding mode to add to your table. Return to the display of oysters to find tiny, tiny snails at the edges of the oyster shells. These

ectoparasites make their living by sucking blood from the mantle tissue of oysters. If any are feeding, you may be able to see (under a dissecting microscope) as they extend the proboscis into the oyster tissue. These animals are also unusual in lacking a radula. (Note: Although *Boonea* looks just like a snail, they are not members of the O. Prosobranchia. Their classification is uncertain, but they are probably more closely related to the next two subclasses, Opisthobranchia and Pulmonata.)

SUBCL. OPISTHOBRANCHIA ("rear gill")

Like all opisthobranchs, the "sea slugs" (O. Nudibranchia) undergo *detorsion* during their development, resulting in an anus returned to its posterior position. Nudibranchs have no shells and no visible mantle cavity or ctenidia. Instead, they rely on exposed outfolds of the body wall (giving rise to the name "naked gills"): either **cerrata** (as found in aeolid nudibranchs) or **anal gills** (as found in the dorid nudibranchs).

You will work with the live aeolid nudibranch *Cratena pilata*, which is common on docks where it consumes colonial hydroids and then lays its white egg strings on the colonies.

Head structures. Examine the head region of *Cratena*. Note a long pair of **cephalic tentacles** that are likely used in chemosensation. **Light sensitive ocelli** may be relatively inconspicuous at the base of the cephalic tentacles. Behind the tentacles is a pair of **rhinophores**, mechanoreceptors that are particularly tuned to detect the direction of water movement.

Cerrata. Much of the rest of the dorsal surface is covered by cerrata, which provide a high surface area for gas exchange. Examine them under the dissecting scope--can you see anything inside these structures? In many species they contain diverticula of the digestive system, within which they can store structures acquired from foods they consume. Some examples:

(1) Certain nudibranchs like *Hermissenda crassicornis*, which feed on hydroids and anemones, can not only get around the defense of their prey's nematocysts but somehow capture the **unfired nematocysts** and store them in the tips of their cerrata, where they become part of their own defense system!

(2) Some can store **spicules** acquired from sponge and cnidarian prey as a structural defense.

(3) Some sacoglossans (another group within the opisthobranchs) can store **chloroplasts** from the plant material they consume, and use the chloroplasts as "endosymbionts" to achieve nutrient gain through photosynthesis!

Circulatory system. Recall that molluscs have a 3-chambered, contractile heart that (in all but the Cephalopoda) leads to an open circulatory system (**hemocoel**). The heart is surrounded by a coelomic space, the **pericardial cavity**, where primary urine is collected. Although the heart of a mollusc is typically hidden under shell or opaque mantle tissue, in *Cratena* it is visible through the relatively thin dorsal dermal layers. Look for its action under the microscope. Note the color of the blood, which carries **hemocyanin**, a respiratory pigment that has copper (rather than iron, as in hemoglobin) as the oxygen binding atom and turns blue when oxygenated.

SUBCL. PULMONATA ("lunged")

The pulmonates (land snails and slugs, freshwater snails, and some high intertidal marine snails) are one of the few groups of invertebrates that have successfully colonized terrestrial habitats. In the process, they have evolutionarily *lost* their ctenidia and modified the mantle cavity into a true and partly enclosed **lung**. Animals take air into the lung, and gases are exchanged across the highly vascularized surface of the mantle cavity wall.

Pulmonates undergo partial **detorsion**, so that the opening to the mantle cavity (the **pneumostome**, or lung opening) can always be found on the **right side** of the body (recall that torsion involved a *counter-clockwise* twisting of the visceral mass, and detorsion a partial reversal of this twisting, a process that puts the opening to the mantle cavity on the right side).

Terrestrial. If available, examine a live or preserved specimen of a common terrestrial garden slug. Find the location of the **pneumostome**, the narrow muscular opening that leads to the mantle cavity, on the right side near the head. Note that after the animal takes a breathe of air, the pneumostome can be closed off using sphincter muscles, and then other muscles surrounding the lung can compress the space in which air is enclosed.

TQ: What are possible advantages of the ability of a terrestrial pulmonate to (1) close off the mantle cavity via the pneumostome and then (2) increase the pressure of air inside the lung?

Freshwater. Several pulmonate lineages invaded freshwater habitats from land; however, they retain the terrestrial condition of *breathing air*. The lung and a space inside the shell can be filled with an air bubble, which the animals can take underwater to continue breathing.

TQ: If a pulmonate snail is small enough it can live continuously underwater because the air bubble can maintain an adequate supply of oxygen by diffusion. As a snail (and its air bubble) become larger this becomes more difficult. Why? (*Hint: this is a scaling argument!)* The same is true for spiders that can trap an air bubble and survive underwater.

Examine any live freshwater pulmonates we have in the lab to distinguish the chirality of shell spiraling.

- *Helisoma trivolvis* is **planispiral** (the shell spirals in a single plane), whereas *Physa acuta* and *Lynmaea peregra* are both **conispiral** (the spiral of the shell forms a cone, because the coil translates down an axis as it spirals).
- The two conispiral shells can further be distinguished by their **chirality**: *Physa acuta* is **sinistral**, and *Lynmaea peregra* is **dextral**.

Be sure you can distinguish the three species based on these shell characteristics.

TQ: Just because *Heliosoma* is planispiral does *not* mean that it lacks chirality. Study figure 12.11 in your textbook (Pechenik 7th ed.) to understand why. Given the way the gastropod body is oriented (dorsal-ventral) in the shell, even a planispiral shell must be either dextral or sinistral. Which is *Heliosoma*, and how can you tell?

- Watch one or more snails in a finger bowl filled with spring water. Also, try putting one of the smaller conispiral snails on a glass slide and then turning it upside-down, as you did with the flatworm, resting it across a small bowl so that you can view the underside of the foot under a microscope. (The periwinkles may also show crawling on the sides of their hexagonal container). Examine the rasping motion of the **radula** against the glass. Look for the **pneumostome** on the right side of the head. Also, the shell may be thin enough to observe the air bubble trapped beneath that supplies air to the lung.

TQ: Examine the pedal musculature under the microscope as the animal moves upside-down on the slide. Can you tell whether these species use direct or retrograde waves to crawl forward?

MOLLUSC REPRODUCTION

In addition to displaying remarkable variation in body plan, the taxonomic classes of molluscs also vary in their reproduction. Although there are some exceptions,

- **Cl. Polyplacophora**: most chitons are free-spawners that produce a *trochophore* larva
- **Cl. Gastropoda**: many snails and their relatives undergo early development within some kind of brooding structure—a hard capsule or a gelatinous egg mass, ribbon, or string, getting rapidly past trochophore morphology and typically hatching *veliger* larvae with a single shell (even when the shell is later lost or reduced, as in opisthobranchs)
- **Cl. Bivalvia**: most bivalves are free-spawners that produce a bivalved *veliger* larva
- **Cl. Cephalopoda**: many octopuses, squid and their relatives undergo early development encapsulated in a gelatinous structure, reproducing once and then dying

Examine different examples of encapsulated development in gastropods under your microsope. Next week you will see squid embryos inside of their gelatinous masses.

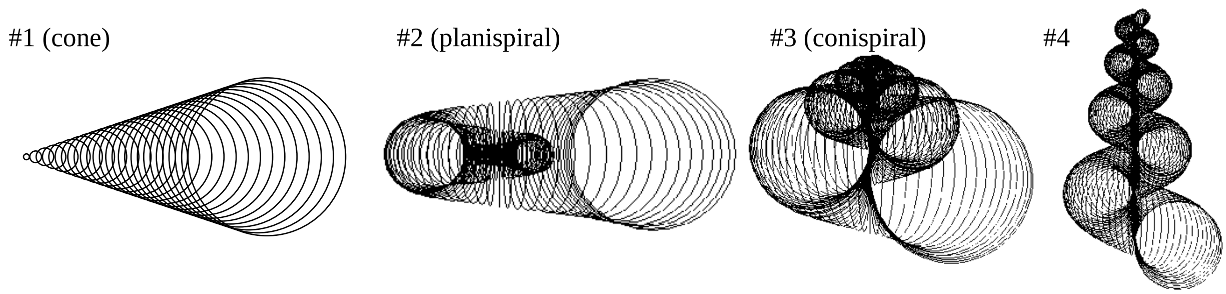
- **FINAL EXERCISE AND TQ**

Enormous diversity among gastropods is reflected in the diversity of their shells. In addition to shells you have seen, consider this small collection from other families. (More are available in the display case in the hallway.) Despite the extraordinary diversity in shapes, biologists have proposed that some very simple mechanisms of shell growth could explain the variation.

TQ1: Explain where material must be added for a shell to grow larger.

TQ2: Examine the four patterns below. Notice the general coiling pattern of these "shells," which were all generated on a computer by varying just a few **rate parameters**. Think of a rate parameter as a dial that you could turn to increase or decrease some rate in how calcium carbonate is added to the shell per turn around the central axis for the animal to grow larger.

Think through and discuss with your lab partner what features change as you move from shell 1 to 2, then from 2 to 3, then from 3 to 4. In each case, try to define a **rate parameter** that can account for each change in form. That is, given your answer to TQ1, what rate could the organism change to create the changes between shells? This is not a simple question, so be sure to bounce ideas off of your instructor!



Change	Assume	What's the difference?	How/where exactly does the snail add shell material to create this change?
From #1 to #2	Equal volumes, aperture sizes	*identify 1 change*	
From #2 to #3	Equal volumes, apertures, number of turns	*identify 1 change*	
From #3 to #4	Equal number of turns	*identify 2 changes*	