SEA STAR DISSECTION **Biology 337**

(Modified from Fox 2001)

The sea star ***Asterias forbesi*** is common in shallow waters along the Atlantic Coast of North America from the Gulf of Maine to the Gulf of Mexico. It is found in areas with rocks and oyster/clam/scallop/mussel beds. As a member of the O. Forcipulatida, this species has pedicillarie and sucker-tipped podia (not true of all orders). Place the preserved specimen in a dissecting pan, and **cover it with tapwater**. Use a dissecting microscope where helpful.

External features

The body consists of a central **disk** from which radiate five **arms** (Fig 1). The principal body axis and axis of symmetry is the very short **oral-aboral axis**, which passes vertically from the **mouth** on the oral side to the **anus** on the aboral side.

Aboral Surface

Find the calcareous **madreporite** on the aboral surface (see Fig 1). Under the dissecting microscope, note its grooved surface. Microscopic pores in the bottoms of the grooves open into two canals (the stone canal and axial canal) of the water vascular system (WVS).

Numbering the arms will aid in your dissection. The madreporite sits on a line between arms **I** and **II**, with arms **III**, **IV**, and **V** continuing counterclockwise around the body (see Fig 1). A radial axis (or **ambulacral axis, as seen on the oral side**) passes down the midline of each arm, dividing it into mirror-image halves. The axis that bisects the angle between any two adjacent arms is an interradial or **interambulacral axis**. Note that one interambulacral axis (between arms I and II) passes through the madreporite.

[see Fig. 1 at back]

On the aboral surface notice the numerous small **fixed spines.** Push on one to see that it is immoble. These spines are extensions of calcareous ossicles in the body wall. Use the dissecting microscope at high power to look closely at the spines. Confirm that they are indeed internal and covered by a thin layer of epidermis. Also examine the base of each spine carefully to find the circle of short-stemmed, white two-jawed **pedicellariae**.

>>> Examine a prepared slide of pedicellariae at high power (400X) to see the numerous ossicle **pores**. This type of construction is typical of **stereom**, the calcium carbonate plates produced by all echinoderms. The pores allow for the growth of connective tissue within ossicles.<<<

DTQ: The porous construction of stereom is also thought to help guard against cracking of ossicles. How would you explain this apparent paradox?

~ answer on main worksheet ~

Between the spines are numerous soft, fingerlike **papulae** (Fig 2), the respiratory structures of sea stars. Visualize papulae as thin-walled extensions of the body wall that bleb out from between ossicles. Cilia on epithelia on the two sides of the papula wall beat to move fluids across the two surfaces, enhancing gas exchange. The papulae can be retracted into the surface of the body wall using muscles, and may be difficult to find in preserved specimens, although the holes through which they project from the body may be visible.

DTQ: What are the two epithelia that make up the thin papula wall? What components of the body wall are absent from this spot? Make a cartoon sketch of a body wall section including a papula. Label the epithelia of the papulae, the fluid spaces on either side of the wall, the location of cilia, and components of the body wall to either side of the papula.

~ answer on main worksheet ~

The **anus** is located near the center of the aboral surface but is almost impossible to find externally. It is surrounded by a set of *tiny* ossicles (much smaller than the spines that stud the surface of the disk) in an area free of papulae.

Oral Surface

Find the large **mouth**, surrounded by the thin, soft **peristomial membrane.** The curtain-like folds of the **cardiac stomach** might be visible inside the mouth.

Five deep **ambulacral grooves** radiate from the mouth along the ambulacral axes (Fig. 3). Numerous **podia** (or **tube feet**) with **suckers**, project from each side of the groove in two rows. The ambulacral groove is bordered by rows of long, flattened **movable spines** on each side (Fig 3)—push on the spines to see if they are movable. ["Ambulacrum" is Latin for "covered way," an apt name given how spines cover the groove and protect the tube feet.]

At the tip of each arm are numerous tube feet with special chemical and mechanical sensors (they may be retracted in preserved specimens). Also at the arm tip are numerous short, blunt movable spines surrounding a small pale **eyespot** (Fig. 1) on the oral surface. The eyespot can be more easily seen in live specimens.

DTQ: How do the positions of sensory structures in cnidarians and asteroids relate to similarities and differences in body symmetry and movement?

~ answer on main worksheet ~

Internal Anatomy

✂ ***Consult Fig. 1 and follow directions before you make all cuts!*** First, use scissors to cut the end from **arm III,** 2 cm from its tip. Then, cut along the two sides of that arm to reach the disk. Extend these cuts across the bases of **arms II** and **IV**, and then stop cutting.

Now lift the aboral body wall **slightly** and with a **blunt probe** carefully free it from the tissues without damaging them. Lift just enough to find the point at which the inconspicuous intestine connects to the body wall at the **anus**. The intestine will be surrounded and obscured by the small lobed **intestinal cecum**. Gently free the cecum from the body wall so that it remains with the rest of the viscera (Fig 2).

[see Fig. 2 at back]

Now, complete your cut across the disk in a convoluted path that leaves the **madreporite** connected to the rest of the body but removes the anus with the body wall (Fig 1). Remove the free portions of the body wall, which will probably destroy the intestine. Set the body wall aside but keep it immersed. Identify these major organs to use them as landmarks (see Figs. 2, 3).

1) The **perivisceral coelom** is the large internal space you have exposed. Contrast this observation with the crab dissection—what space was exposed when you removed the crab's carapace? ______________________

2) The **cardiac stomach**, a large mass of thin tissue, occupies most of the central area. This stomach is highly extensible, and can be enlarged outside the body to engulf large prey.

3) Two large **pyloric ceca** (= digestive ceca, digestive glands) extend out into each arm, occupying most of the aboral space of the perivisceral coelom.

4) Lift the pyloric ceca to reveal the floor of the arm. The raised **ambulacral ridge** (Figs 2, 3), is the internal side of the ambulacral groove you saw on the outside of the arm. Notice how the ridge is formed from sequentially arranged **ambulacral ossicles** in the body wall. The grooves between ossicles, containing connective tissue, give the ridge a striated appearance.

5) On either side of the ridge is the double row of bulbous **ampullae** of the tube feet, part of the water vascular system. Each tube foot projects through a hole in an ossicle of the body wall.

Body Wall

Examine the cut edge of a part of the **body wall** under magnification. The **connective tissue dermis** is the thick layer between a thin epidermis and a thin, inner peritoneum (Fig 3). The dermis contains collagen fibers and calcareous dermal **ossicles**, some of which bear spines. The ossicles may have been crushed by scissors, but an ossicle edge may be clear in some places.

Coelom

Study the *inner aboral* surface of the arm portion of body wall that you removed. It is covered by the thin **peritoneum** of the perivisceral coelom, with cilia that circulate coelomic fluid to distribute nutrients and oxygen to the surrounding tissues. Examine the numerous small pores in the body wall and observe how the peritoneum extends into them. Using magnification and light from below, look *straight* into one of the pores and you will see that it opens into a **cluster of papulae**.

Note that many of the organs enclosed within the perivisceral coelom, such as the pyloric ceca and gonads, are suspended from the body wall by mesenteries (Fig 3). The mesenteries were pulled apart when you removed the aboral body wall.

Digestive System

The very short gut consists of **mouth**, **esophagus**, **cardiac stomach**, **pyloric stomach** (with **pyloric ceca**), **intestine** (with **intestinal ceca**), and **anus**. The thin-walled **cardiac stomach** fills most of the disk perivisceral coelom (Fig 3). Remarkably, this stomach can be **everted** from the mouth to surround prey. The walls are so thin that the stomach can be slipped between the valves of a bivalve if they can be pried open slightly by the pull of tube feet!

Thus, digestion begins **externally and extracellularly** in the cardiac stomach while the prey, and stomach, are still outside the body. The products of digestion are moved to the pyloric stomach and then stored in the cells of the pyloric ceca or diffused through the gut wall into the surrounding perivisceral coelom. Five pairs of **stomach retractor muscles** (mostly connective tissue) anchor the cardiac stomach to the ambulacral ridges (Fig 2). The cardiac stomach opens at its aboral end into the much smaller and pentagonally shaped **pyloric stomach** (Fig 2).

The two large **pyloric ceca** in each arm are hollow sacs, connected to the pyloric stomach by a common duct (Fig 2). Within the cecum, tiny food particles produced by digestion in the cardiac stomach are phagocytized and digestion is completed **intracellularly**.

✂ Cut or tear one of the pyloric ceca to see that it is hollow. The intestine and intestinal cecum, which lead from the stomach to the anus, may have been destroyed by the dissection.

✂ Open the cardiac stomach and look inside. Push the billowy folds of the cardiac stomach aside and trace the gut down to the mouth. The short and indistinct region between the cardiac stomach and the mouth is the **esophagus**.

✂ In order to remove the stomach, *in each arm* carefully cut the pyloric duct and the two stomach retractor muscles. Then cut the connection between the esophagus and **peristomial membrane**. Try not to damage the underlying tissues.

Water Vascular System

By removing the gut, most of the central features of the water vascular system are revealed (Fig 2, 3, 4). Gently lift the part of the aboral disk containing the **madreporite** and look below it for the **stone canal**. This curved duct extends orally from the madreporite and has calcareous skeletal rings for support. Because it is calcified, it is firm to the touch.

Follow the stone canal to where it meets the inner edge of the circular skeletal ring known as the **mouth frame** (Fig 4). The stone canal connects here to the (very inconspicuous) **ring canal** of the WVS. The position of the ring canal can be visualized by **nine** small, spongy **Tiedemann's bodies** (Fig 4), which are evaginations of the ring canal. These bodies are thought to phagocytize foreign particles in the circulating fluid of the WVS. You may also see the **ten** ampullae of the tube feet on the aboral surface of the mouth frame. They connect to enlarged buccal tube feet around the mouth.

Like the ring canal, the **radial canals** that run from the ring canal out each radius, and the **lateral canals** that arise alternately to the right and left of the radial canal (Fig 3) are difficult to see. Each lateral canal, however, leads to a single **tube foot** and its **ampulla**, which are visible. The tube foot narrows, penetrates a pore through the **ambulacral ossicle**, and emerges from the ambulacral groove, which you've already seen.

Both the perivisceral coelom (which you are looking into) and the WVS (including the inside of the ampulla and tube foot) are coelomic cavities. Think through the tissue layers you would need to go through with a microneedle to get from the perivisceral coelom out to seawater by way of a tube foot. First visualize how the basal lamina of the ampulla peritoneum faces the basal lamina of the perivisceral peritoneum.

DTQ: Now draw (#1) the orientation of the two tissues below, spanning a field with two ampullae, using cilia to denote the apical sides of cells. Then, in the same way, draw (#2) the orientations of the tube foot peritoneum and the epithelium that covers each tube foot as it emerges on the other side of the ambulacral ossicles (spanning two tube feet):

~ answer on main worksheet ~

Use a microneedle to push aside an ampulla to see that it narrows into a slender tube that penetrates the ambulacral ridge. Insert the needle and pass it through the ampulla and the pore to emerge on the other side in the lumen of a tube foot. You should, of course, now know the 2 epithelia you penetrated to get there, and the remaining 2 you would penetrate to get to seawater.

Reproductive System

Asteroids have separate sexes and fertilization is external. Each individual has a pair of **gonads** in each arm (Figs 2, 3). If ripe, the gonads may fill the remainder of the perivisceral coelom. If the specimen is immature or unripe, they may be difficult to find. If they are small, they will be located on the oral surface of the base of each side of each arm. Every gonad connects to its own tiny **gonopore** on the aboral surface on each side of the base of the arm.

The following four sections describe structures that would be difficult to see in dissection. This information is provided for reference, and should be read later.

Nervous system. The nervous system consists of a **nerve ring** that runs around the mouth; **radial nerves** that run from the nerve ring down each radius to the eyespot, within a thickened band of epithelium on the roof of the ambulacral groove; and a large diffuse **nerve network** of throughout the epithelia of the body wall. In this sense the nervous system resembles the diffuse nerve net of cnidarians, which are also radially symmetrical.

Hemal system**.** The hemal system is the least understood of echinoderm organ systems. As is typical of a blood vascular system, it consists of a space through connective tissue. It is atypical in that the blood vessels end blindly, with no continuous path of blood circulation. The hemal system lies in the 3rd coelomic space, the **hyponeural coelom**, just above the radial nerve.

Respiratory system. In echinoderms the hemal system *does not* distribute oxygen to the tissues. Instead, the perivisceral coelom circulates oxygen taken up across the papulae, and the WVS circulates oxygen taken up across the tube feet.

Excretory system. Echinoderms are not known to have special osmoregulatory or excretory systems, and they occur exclusively in saline waters. The end product of nitrogen metabolism is ammonia, which in asteroids is eliminated by diffusion from the papulae and tube feet.

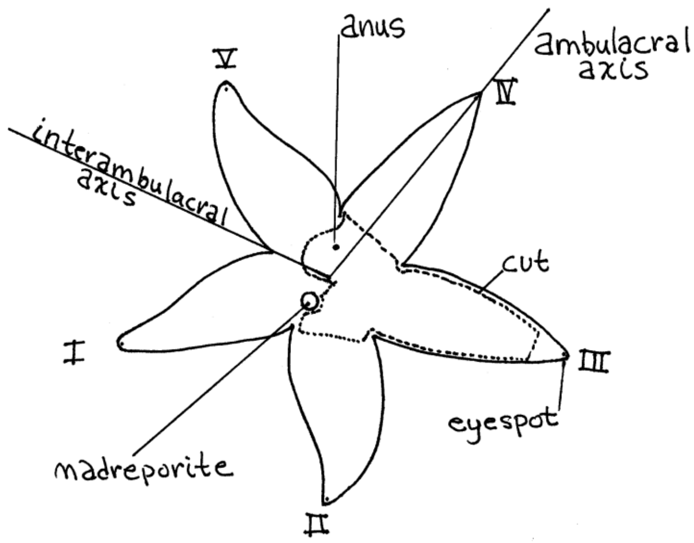


Figure 1 Aboral view of *Asterias*.

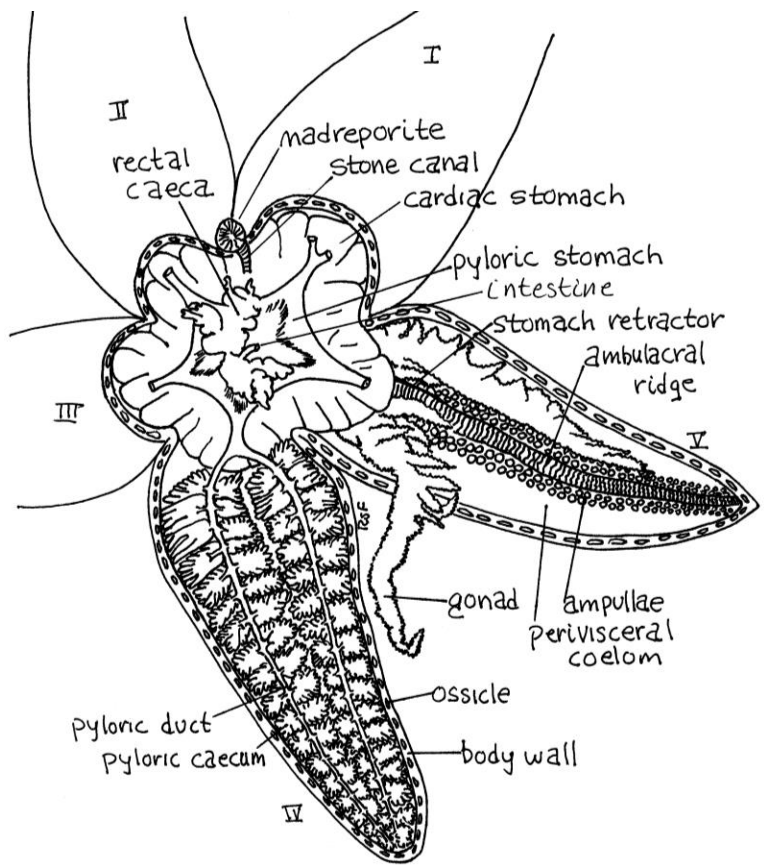
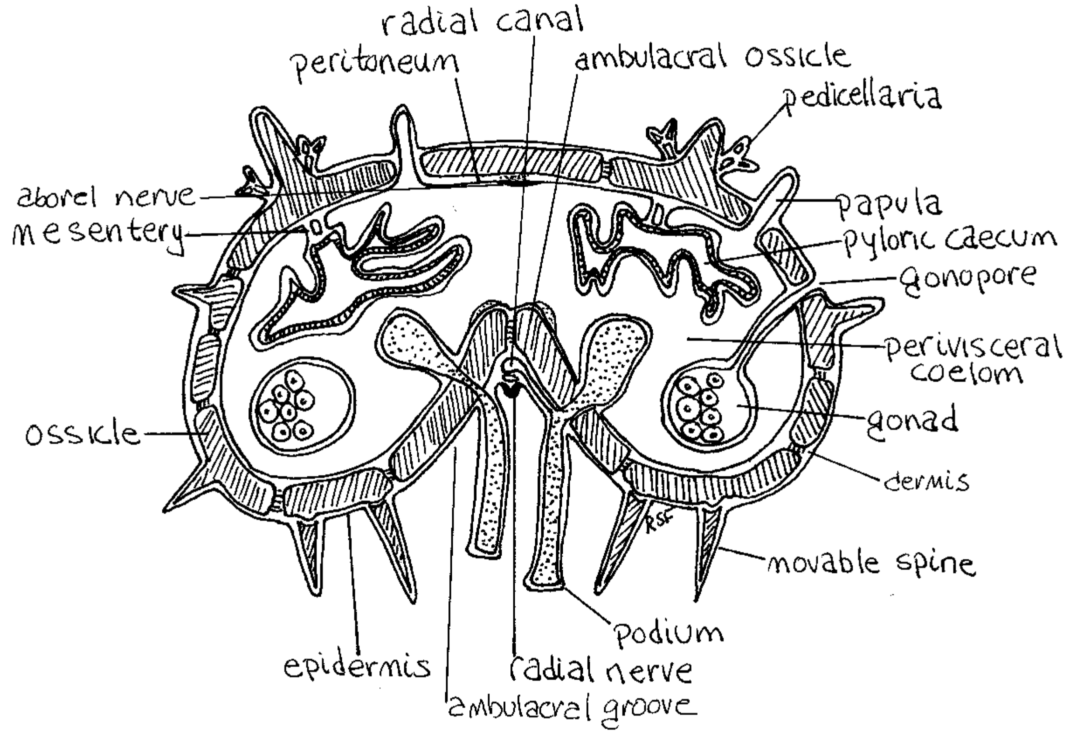


Figure 2. *Asterias* in aboral view with the body wall removed from the disk and two arms. The pyloric ceca have been removed from arm V.

Figure 3. Cross section of an arm of *Asterias*.



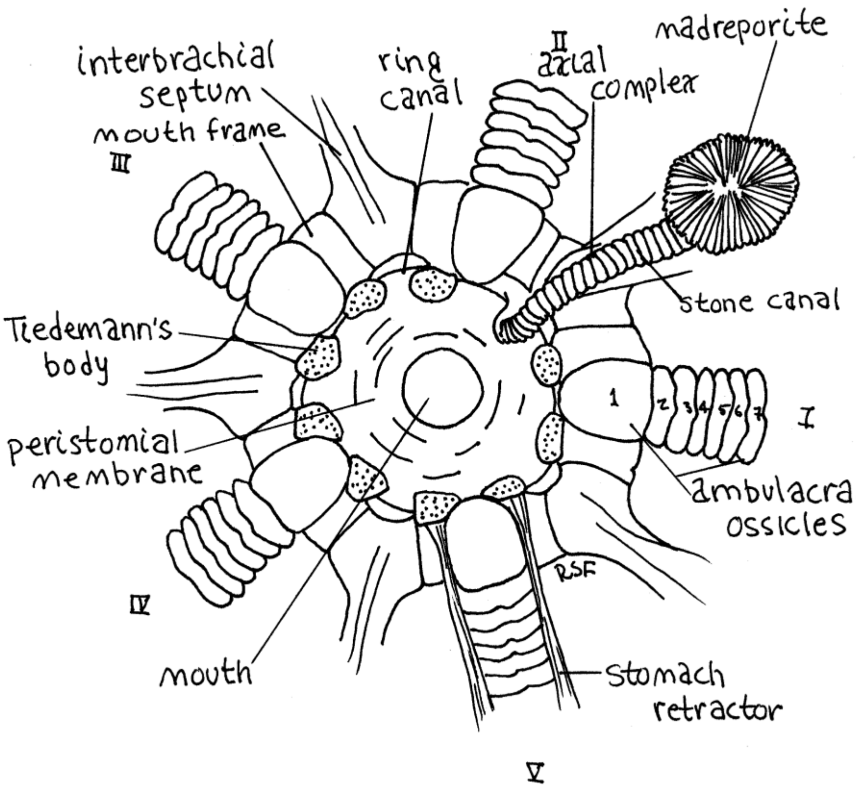


Figure 4 Aboral view of the mouth frame of *Asterias*.