Animal Diversity III – Deuterostomes

In this third and final animal diversity lab, we will study the **deuterostomes**, which include phylum **echinodermata** and phylum **chordata**. Though echinoderms and chordates outwardly seem very different, they share common features in their early development that distinguish them from other bilaterally symmetrical animals. Remember in deuterostomes, the embryonic blastopore gives rise to the anus. In the protostomes, which includes annelids, arthropods, and mollusks, the blastopore gives rise to the mouth. Although adult echinoderms have radial symmetry, their larvae are bilaterally symmetrical, thus they are classified along with chordates as **bilaterally symmetrical**.

Phylum Echinodermata

The echinoderms include sea stars, brittle stars, sand dollars, sea urchins, and sea cucumbers among others. Echinoderms are exclusively marine animals. Some are predators; others are foragers or plankton feeders. Although adult echinoderms have radial symmetry, their larvae are bilaterally symmetrical, thus they are classified along with chordates as **bilaterally symmetrical**. Not only do echinoderms have a coelom, they also have complex organ systems. A unique feature of echinoderms is a **water-vascular system.** This is an interconnected network of tubes and tube feet that radiate out from a central canal surrounding the gut. The water-vascular system circulates nutrients and oxygen and helps to get rid of waste. It also enables the use of tube feet for locomotion and for capturing and holding prey. Just beneath the skin lies an **endoskeleton** composed of ossicles made of calcium carbonate. In sea urchins, the ossicles enlarge and fuse to form a rigid case, called a test, while in the sea cucumbers the ossicles are small and isolated. The nervous system is usually composed of a central ring from which nerves radiate.

Be sure to take a look at the examples of echinoderms on display in lab.

Exercise 1 – Sea Urchin Embryology

1. Your instructor will demonstrate how gametes are obtained from the urchins.

2. Place a drop of egg suspension on a glass depression slide and observe under 40x. While you are focusing on the eggs, your instructor will add a small drop of sperm suspension. Focus on the eggs. Coverslip will be added either before or after adding sperm depending on which method works best. Note the time.

3. Continue to observe the eggs for a few minutes. Watch for the formation of the feritilization membrane.

Sketch what you observe. Be sure to note time of observations.

4. Observe the eggs at frequent intervals during lab. However, do not prolong the periods of observation under the light of the microscope and be sure to turn off the light between observations. Excessive heating will kill the embryos. If fertilization has occurred, you can expect the first cleavage to occur after 50-100 minutes.

   Sketch what you observe (note time):

5. If available, observe fertilized eggs from earlier sections. The swimming **blastula** stage normally occurs approximately 24 hours after fertilization. The blastula consists of a hollow ball of cells. The **gastrula** stage occurs after about 2 days. This stage begins the differentiation into the three embryonic germ layers: ectoderm, mesoderm, endoderm.

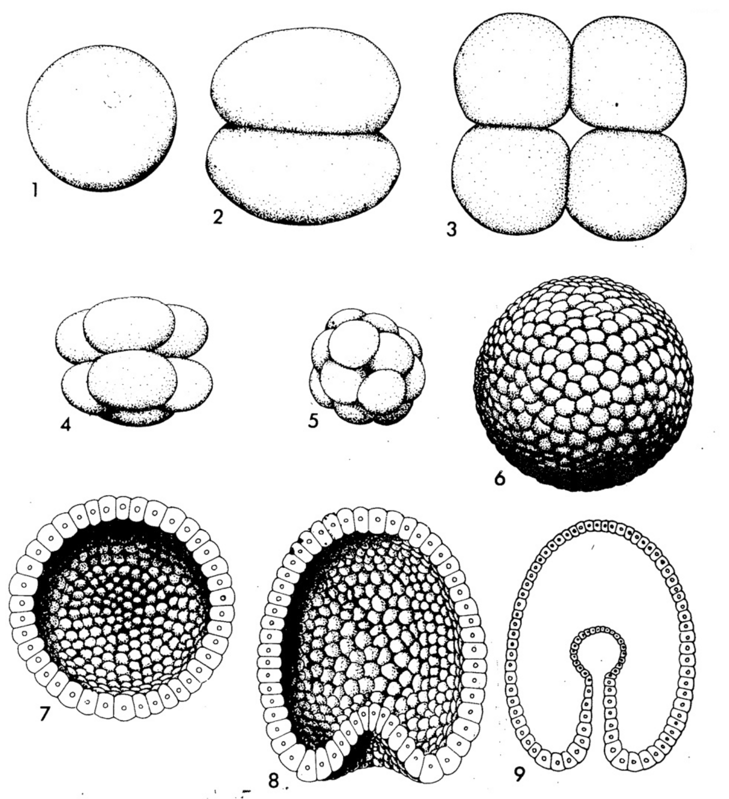
   Sketch your observations:

Approximate times for the early stages of development for *Strongylocentrotus purpuratus*, a west coast species:

Fertilization Membrane Forms	2-5 minutes
First Cleavage	50-100 minutes
Second Cleavage	100-120 minutes
Third Cleavage	130-160 minutes
Blastula	24 hours
Gastrula	2 days
Pluteus larva	5 days

The final stage of metamorphosis from a pluteus larva to a baby sea urchin takes several months. The entire process, from fertilization to reproductive adult, takes 2-5 years.

Figure 1. Early Stages of Sea Urchin Development



1. Fertilized egg (without fertilization membrane)
2. Two-cell stage
3. Four-cell stage
4. Eight-cell stage
5. Morula stage
6. Blastula
7. Blastula (open view)
8. Beginning of gastrula
9. Later gastrula

Exercise 2 - Sea Star, external structure

Place a preserved sea star in a dissecting pan, oral side down. Use a dissecting microscope and adjust the light source to see various structures mentioned below. Use diagrams available in lab to help you identify structures.

1. Aboral surface - Small non-movable spines extend from the endoskeleton. Around each spine is a cluster of pincer-like structures. These function in cleaning the surface of the sea star. Gas exchange also occurs through the aboral surface. On the tip of each arm is a single, slightly enlarged ossicle. It contains a small, pigmented eyespot that is light sensitive (in preserved specimens, the eyespot is often bleached and difficult to see so you might look at a live specimen in the aquarium for this.) In the center is a small disk devoid of spines through which water enters and exits the water-vascular system. The anus opens in the center of the central disk, but is small and inconspicuous.

2. Oral surface - Turn the sea star over. Down the middle of each arm runs a groove covered with tube feet. If necessary, spread apart the groove to expose the feet. They are especially evident near the base of the arm. Scrape away a few tube feet to find the pores through which the feet extend. Sea Stars can vary the water pressure in these feet and use them in concert to move over a substrate or grasp food. The mouth of the sea star is at the center. Sea stars can evert their stomachs through their mouths to surround and digest food. The mouth on your preserved specimen may be filled with a partially everted stomach.

Phylum Chordata

Hemichordates and chordates, like echinoderms, are also part of the deuterostomes, a group with fossil records dating to over 500 million years ago. Following are key structural features of chordates.

Major Characteristics of Chordates:

Notochord. A notochord is the key feature that distinguishes chordates from other animals. A notochord is found in all chordate embryos and some adults. It is a slender rod lying between the dorsal nerve cord and the gut. It provides a flexible structure that supports and permits sideways bending of the body for swimming motions. In adult humans, the notochord remains as the vertebral disks.

Pharyngeal slits. The pharynx is part of the digestive tract, located just behind the mouth. At some point in their lives, all chordates have pharyngeal slits (or gill slits) where the sidewalls of the pharynx open to the exterior. Pharyngeal slits permit a one-way flow of water in the mouth and out through these slits.

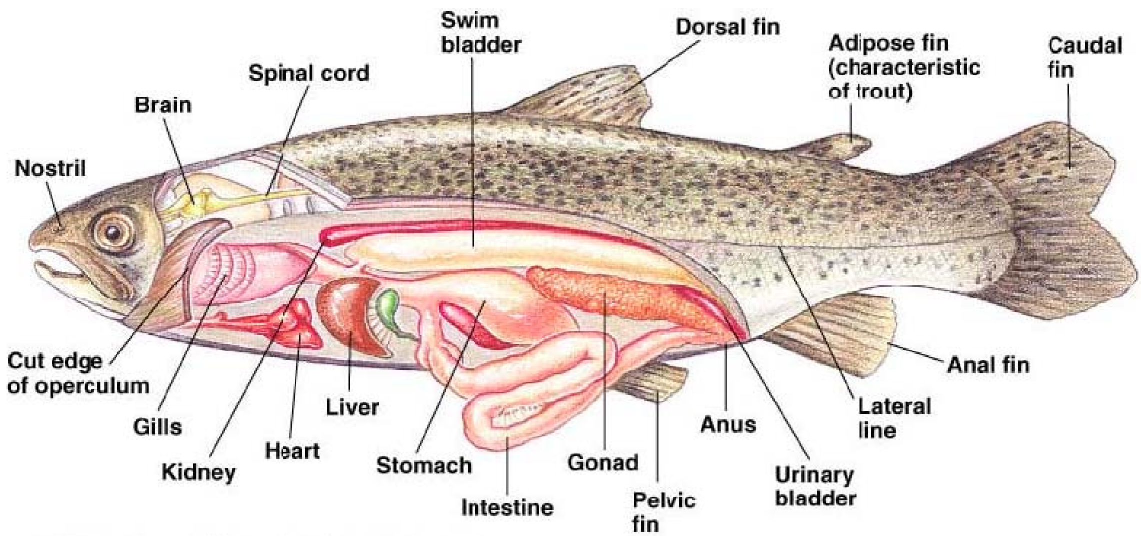
Dorsal tubular nerve cord. In chordates, the nerve cord is a hollow fluid-filled tube, in contrast to the solid structure found in other deuterostomes. The nerve cord is located dorsal to the gut.

Post-anal tail. Chordates have a muscular/skeletal tail that extends beyond the anus. In other animals, the digestive tract extends right to the end of the body. Tails are typically used for balance and swimming. In some chordates, like humans, the tail is lost during embryonic development.

Exercise 3 – *Perch Skeleton*

Observe the perch skeleton on display in lab to find the following parts. There are three sets of bones: the **skull, vertebral column**, and **appendages**. Notice that the vertebral column is composed of a series of repeating segments. Pairs of ribs project out from the vertebral column in the trunk region. In the caudal, or tail region, these ribs give rise to spines. The point where ribs are replaced by spines is the dividing line between the trunk and tail regions of the vertebral column. Appendages include the fins and their associated girdles (found at the bases of the fins, but are difficult to see).

Figure 2. Diagram of a trout



Exercise 4 - External structures of a fish

Place the fish on its side in a dissecting ray. Identify general regions: head, trunk, and tail. Note the general features of external anatomy: eyes, pair of double nostrils, mouth, and tail ending in a caudal fin (Figure 2). Along the dorsal surface are two dorsal fins. Find the anus, a small ventral opening that lies just anterior to the single anal fin. A pair of ventrally positioned fins, the pelvic fins, are located anterior to the anus. The pectoral fins are located on the sides of the body. The faint, thin line along the side of the fish, halfway between pectoral and dorsal fins, is the **lateral line**, an important organ that can sense changes in pressure.

Behind each eye is a large flap, the **operculum,** which covers the feathery **gill lamellae**. Lift the operculum and run your blunt probe along the curve of these gill lamellae to feel the solid bar that supports them, the **gill arch**. Force the operculum well forward to get a good look at the arches. The space between each arch is the **gill slit**. Notice the row of little knobs around the inside bend of each gill arch, these structures are called gill rakers. They intercept food particles suspended in the passing current of water. Slip a blunt probe through the mouth and out through a gill lamellae. Next, use your scissors to cut through the angle of the jaws on the right side back across the base of the operculum. Lift the upper edge of this cut to observe the path followed by water, which enters the mouth and exits through the gill slits. Return briefly to the mounted perch skeleton to locate these same structures or their approximate positions relative to the bony skeleton.

EXERCISE 5 -Viscera of a fish

To examine the viscera, follow the directions below to cut out the side of the fish overlaying the viscera. While making the necessary cuts, try not cut into organs underlying the body wall. Use the perch dissection guides, provided in lab, to help you locate and identify structures.

Using *scissors*, insert one blade into the anus and cut forward along the ventral surface just past the pectoral fins. Turn the scissors and cut upward behind the operculum to just below the lateral line. Turn the scissors again and extend the cut posteriorly, parallel with and below the lateral line, until you reach a point approximately even with the anus. Finally, cut down to your original starting point. Cut away points of attachment so as to free this piece of body wall. The side of the body should now lift away to reveal the organs underneath.

The gonads are often the largest single organs. Locate the gonads. **Is the gonad of your fish a testis (smooth) or ovary (granular)?**

Pull the exposed gonad away by its anterior end and either tear it free or push it aside. The other gonad on the opposite side can be seen through a shiny membrane, the mesentery. Gently shift the other organs to confirm that the mesentery also runs between them. An air bladder may be present which occupies the dorsal region of the coelom. It is also a shiny structure, but its walls are thicker. Locate the kidney. It is found flat against the dorsal wall of the coelom along the midline up against the vertebrae. In fresh or frozen specimens, the kidney is usually dark red in color.

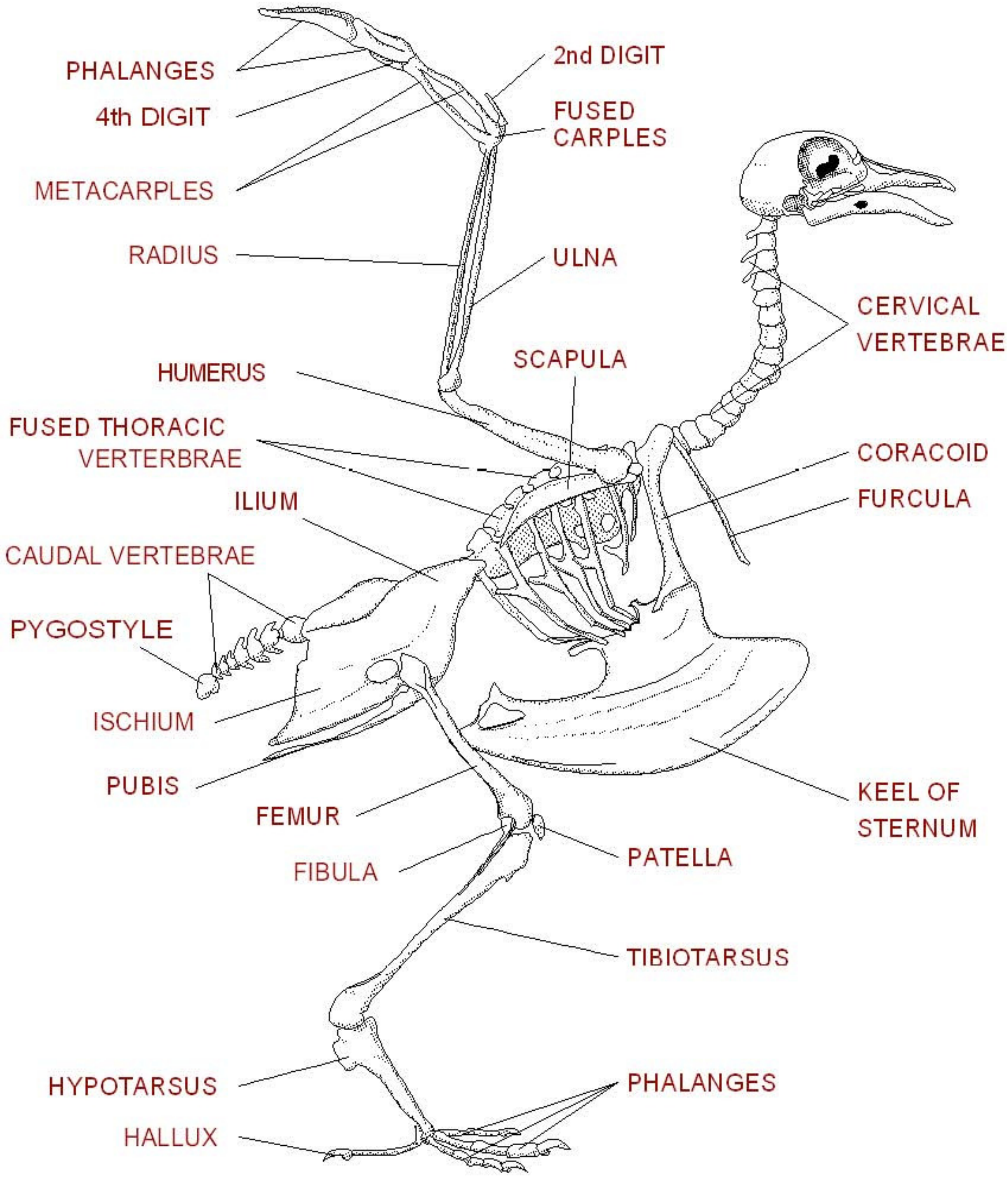
Locate the bent and folded tubular **intestine** that lies along the ventral part of the coelom. Note that it continues to the anus. With a blunt probe, lift the folds of the intestine aside to find an elongate gray organ suspended in mesentery. This is the **spleen**, a reservoir for blood. Yellow streaks in the mesentery are deposits of stored **fat**. Just dorsal to the folds of the intestine is the swollen blunt **stomach**. The **liver** is the larger, lobed organ occupying the anterior wall of the coelom.

To confirm your identification of parts of the digestive tract, follow the course of food from the mouth into the stomach. If necessary, deepen the cut made previously through the middle of the gill arches. Force back the side of the cut to see the channel from the mouth to the beginning of the stomach. Insert a blunt probe into the opening and push it into the stomach until you can feel the tip inside the stomach. Now find the point where the stomach joins the intestine. The short region of the intestine that connects to the stomach is the duodenum, important in digestion and absorption of nutrients. The remainder of the intestine is not differentiated into large and small portions. Between stomach and liver lies a gall bladder. A pancreas is found scattered about the mesentery.

Next, examine the stomach contents by cutting into the stomach. If you find something in the stomach, put these contents onto a slide and examine them under a dissecting scope to see if you can identify any food items.

You may need to extend the ventral incision forward to locate the **heart**. The heart has two major chambers, the **atrium** and the **ventricle**. The dark flap of tissue is the atrium that lies upon the dorsal surface of the tan ventricle. Keep in mind the structure of this heart so that you can compare it to the heart of the quail.

Figure 3. Skeletal structure of a pigeon



Exercise 6 – Skeletal system, pigeon

Examine the pigeon skeleton on display in lab and refer to Figure 3 above. As with the fish, there are three regions: skull, vertebral column**,** and appendages. The vertebral column has several regions: a cervical region between skull and base of the neck; next is the thoracic region, associated with ribs; the sacrum fused with pubis; and finally the pygostyle (the tail bone composed of several fused vertebrae). The appendages not only include limbs, but additional bones that project out from the vertebral column. The pectoral girdle is a group of bones involved in attaching the wings to the vertebral column. The pectoral girdle includes the scapula (shoulder blade) and fused clavicle (collar bone) to make the coracoid or furcula (wishbone), necessary for attaching muscles used to move the wings and neck. The pelvic girdle is a single unit formed by the fusion of three separate bones (ilium, ischium, pubis) that are so completely fused that boundaries between them cannot be seen in adult birds. In each forelimb there is a humerus, radius, and ulna; a fused bone, carpometacarpus (the carples and metacarples); and several digits or phalanges. Each hind limb includes a femur, large tibia, small splint-like fibula, composite tibiotarsus, and several digits. The area enclosed by the ribs and sternum is the rib cage.

The skeleton of a bird is derived from an ancestral dinosaur, but has some key adaptive features making them more suitable for flight. Many bones are fused, for example, most of the pelvic region, the tailbones, the wishbone and many vertebrae. Other vertebrae that are not fused interlock with adjoining vertebrae to give support. This fusion strengthens these areas from stress due to flight. Flight also requires reducing weight. For example, birds do not have teeth and their skulls are quite small relative to their bodies. They also have hollow bones made stronger by internal struts. The drumstick, tibiotarsus in chickens, is hollow. Notice the large sternum, also called keel or carina. The large surface area of this structure is used to solidly anchor the strong flight muscles. The wishbone is oriented “upside down” to counter the force of the flight muscles and to prevent the collapse of the chest cavity.

What key adaptations of a bird skeleton have evolved for flight?

Not all birds fly. In flightless birds, as you might expect, the wing is smaller relative to body size. In addition, the keel or carina is significantly reduced. Indeed, one can deduce how much flying birds do by comparing the size and shape of the carina.

Exercise 7 - External Anatomy: *Quail*

Spread the wings to find the primary feathers that attach to the carpometacarpus and digits, and the secondary feathers that attach to the ulna. The primary feathers are most important in providing thrust during flight. The secondaries provide lift in gliding. The body is covered by contour feathers to streamline the shape.

The caudal vertebrae support the tail feathers for balance. Beneath the contour feathers are small feathers for insulation. At the base of the tail is the cloaca, the opening used for digestive, urinary and reproductive tracts.

Exercise 8 - Internal structures: *Quail*

Note: Use the diagrams provided in lab to help you identify the internal structures of the quail.

Dissection of the bird will involve cutting through the ribs and lifting the sternum out. To expose the viscera, place the quail on its back in the dissecting pan. Use your finger to feel along the sternum (toward the cloaca). Once you reach the base of the sternum, pull up the skin and feathers to make a small cut just below the base of the sternum. Use your finger to widen the opening. Once the opening is widened, place one hand on the lower portion of the body (such that you are not crushing the organs), then use your other hand to lift the sternum (carina) toward the head. Once you have lifted the carina you will have to use scissors to finish removing the rib cage, etc. Take care that the scissors do not gouge organs within the rib cage. Lift the posterior edge of the carina; cut through bones that continue to hold it. These will be the carocoids and furcula. As these are cut, the carina should lift free to expose viscera within the coelom.

The single median structure is the heart. There are four chambers to the bird heart: a pair of atria and a pair of muscular ventricles. **How does this differ from the fish heart?**

The two dark structures to either side and behind the heart are lobes of the liver. Also next to the heart, but resting along the dorsal body wall, are the spongy lungs – one on each side. Find the ringed trachea next to the esophagus. Follow the trachea to confirm its connections to each lung. As in the fish, a clear membrane, the mesentery, surrounds the organs.

To trace the digestive tract, begin by finding the gizzard. This is a hard, muscular structure, found dorsal to the left lobe of the liver, which is responsible for grinding food. Find the connection with the crop. Then find where the esophagus joins and expands to form the crop. The intestine starts on the medial side of the crop. The first part of the intestine is the large duodenum. Within its folded coils is the tan-colored pancreas. After the duodenum, the intestine narrows into a very long but highly coiled small intestine. Free it from the mesentery to inspect its length. The last, enlarged inch of the intestine is the large intestine. The external opening, the cloaca, connects to both the digestive tract and the reproductive organs.

Rotate the gizzard out of its normal position to discover the dark bean-sized spleen, not to be confused with either lobe of the liver. Dorsal to the large intestine are the dark kidneys that occupy a recess in the roof of the body cavity. If your quail is a female, only one gonad (ovary) is present, not a pair, and is accompanied by the genital duct (oviduct or vas deferens). Alternatively, if your bird is a male, then you will see two gonads (paired testes), accompanied by the genital duct. NOTE: For female birds you may also find eggs still present in the oviduct, including multiple developing yolk follicles (early stages of egg formation).