

LABORATORY *12*

Cephalopod Adaptations


INTRODUCTION:

Cephalopods are found throughout the world's oceans, from shallow, tropical, warm-water reefs to the cold depths of the **bathypelagic** realm and beyond. There are two groups: the family that contains a few species of *Nautilus*, famous for its pearly shell, and the squid, cuttlefish, and octopus family, containing nearly 700 species. Cephalopods are recognized as being the most intelligent invertebrates, and some squids rival fish in terms of their swimming speed. There are planktonic, nektonic, and benthic species; all are efficient predators. Furthermore, several species support major fisheries in Asia, the west coast of the United States, and South America.

The goals of this laboratory are for you to accomplish the following:

- Locate and identify internal and external features of the anatomy of a squid.
- Understand the functions of the various anatomical structures.
- Understand how the squid's adaptations help the animal survive in its environment.
- Compare and contrast the anatomical adaptations of a benthic and a pelagic cephalopod.

You will perform a simple dissection of the Pacific market squid (*Loligo opalescens*). Before beginning this exercise, make sure that you understand the proper dissection and safety procedures, as explained to you by your instructor.



DVD: Before the day of the laboratory, please review the DVD chapter for this activity.

I. EXTERNAL ANATOMY

Lay the squid vertically in your dissecting pan, with the animal's posterior end at 12 o'clock and the side with the **siphon** facing you (Fig. 1). The siphon is a tube of tissue that projects downward between the eyes.

Survey the overall body of the squid. This animal needs to solve the problems of finding food, getting oxygen, reproducing, and moving through its environment. Cephalopods have evolved particular adaptations that provide solutions to those problems.

You see the **arms**, the **head** with eyes, and the tubular **siphon** pointing downward between the eyes. Above the head is the body, enclosed by a muscular covering called the **mantle**. The squid forces water from the mantle through the siphon to propel itself through the water.

Is the siphon flexible?

How do you think the squid changes direction while swimming?

Compare the shape of the squid's mantle with the mantle of an octopus. How do they differ?

The squid's mantle bears structures called **fins**. Why would a **pelagic** (living in the open ocean) cephalopod have fins and a **benthic** (living on or near the sea floor) one lack them? (Hint: What is the function of fins on a surfboard?)

Therefore, fins must have an important role in _____ the animal while it swims.

What are 3 words that describe the shape of the animal's body?

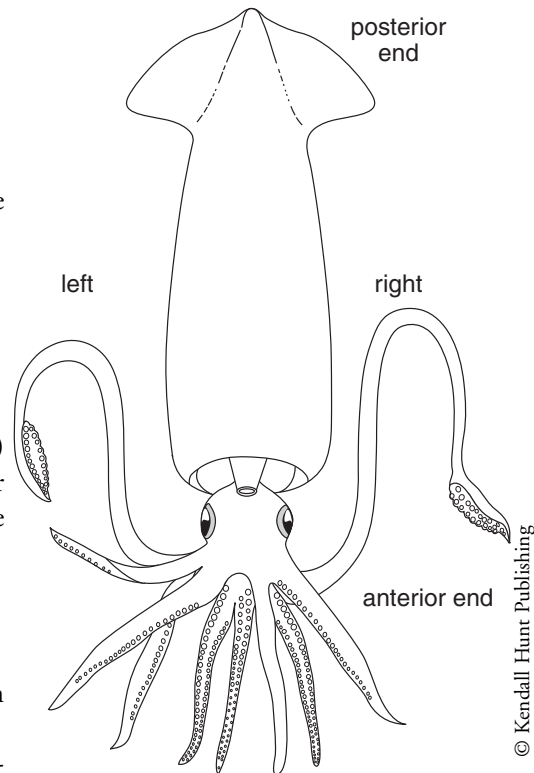


Figure 1. Ventral view of the common market squid *Loligo*.

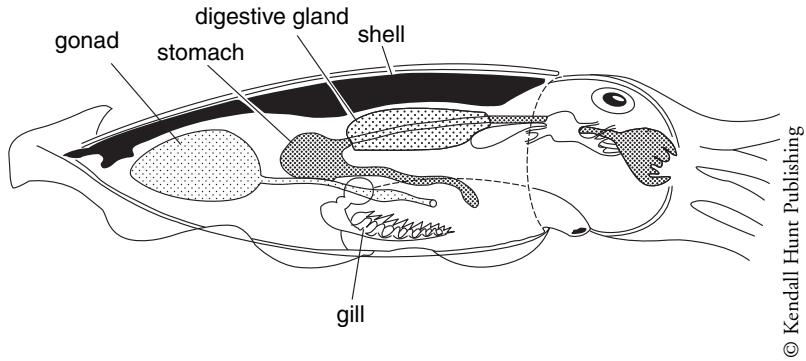
Feel along the edge where the mantle meets the head; you should feel a pointed structure. This is the tip of the **pen**, also called the **gladius**. It feels like plastic, but it is made from **chitin**, the same flexible protein material found in crab and shrimp shells. Leave the pen where it is; you will remove it **after** you have examined the internal organs. The pen is a remnant structure—ancient cephalopods had an external, calcareous shell, but through **evolution**, the shell gradually became smaller, lighter, and internal—characteristics that confer a significant survival benefit to the modern-day organisms possessing them. In what way do these characteristics help a cephalopod survive in its habitat?

The internal shell of cuttlefish is made of a light material called **cuttlebone** (Fig. 2a, b).

If the squid's mantle lacked rigidity, how would that affect its swimming speed?

What do you conclude is one function of the pen?

What can you infer about the swimming speed of the squid, based on its general appearance and the role of the fins and pen?



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Figure 2. (a) The internal shell from the cuttlefish *Sepia*, left.
(b) The way the shell is positioned within the animal's body, above.

Notice that the skin has spots of various sizes. These are **chromatophores**, which are pigmented bodies within skin cells that enlarge or contract, due to the contraction or relaxation of tiny muscle fibers attached to them. If you are using a frozen squid, you can rub the skin vigorously with your finger, which may cause the skin to darken. To view chromatophores in more detail, peel off a small portion of darkened skin tissue, make a wet mount of it on a slide, and examine it under the compound microscope. Make a sketch below:

DVD: Squid Congregation

In the video of squid courtship and mating, how were chromatophores important? When chromatophores enlarge, how does this affect the color of the animal?



Squids have two types of appendages. One type is longer and has a fleshy pad with larger suckers on it. How many of these does the squid have?

How many appendages are shorter?

These long and short appendages are the **tentacles** and **arms**, respectively.

Examine the suckers on the arms and tentacles, and run your fingertip lightly over the suckers. What are the differences that you notice? Draw details of both kinds of suckers below.

An internal structural difference between the 2 types of appendages is in the diameter of the blood vessels supplying each type. The tentacles have larger diameter blood vessels, which indicates that the colorless blood can be pumped rapidly down the length of the tentacle. When this occurs, how does this affect the length of the tentacle?

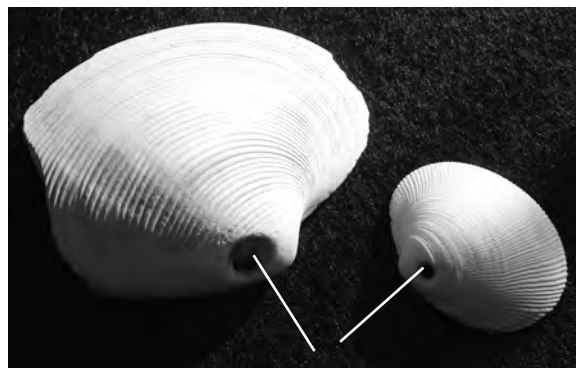
After the squid captures its prey, it holds it in its arms and consumes it. So where is the mouth found?

Locate where you think the mouth must be. Cut between the 2 arms, directly below the siphon, to separate the arms and to expose a round, tough structure called the **buccal bulb**. Cut this open with your scalpel to expose the mouthparts, called the **beaks**. Use your fingers to make them open and close. Are the beaks adapted for grinding food or for ripping flesh?

Draw the beaks below.

Between the beaks is the **radula**, a small yellowish-white ribbon of hard tissue that acts like a toothed tongue to shred food and transfer it into the esophagus. The radula may be hard to find within the mass of other tissues. Use your probe and forceps to pull apart the tissues little by little to expose the radula. Remove it, make a wet mount of it on a glass slide, and examine under a compound microscope. Make a sketch of it below.

Octopuses also use the radula to drill holes through the hard shells of bivalves and crustaceans (Fig. 3). Around the mouth are glands that produce digestive fluids and paralyzing toxins to incapacitate the prey.



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Figure 3. Radula damage on bivalve shells; evidence of predation by a carnivorous mollusc such as an octopus.

After food is swallowed, it travels through the **esophagus** up through the head and into the stomach. You will have to cut open the mantle to view the digestive system. The mantle is thick and

muscular, and it is the source of calamari “rings” and “steaks” that we eat. The mantle covers and protects the internal organs.

II. INTERNAL ANATOMY

Use scissors to make a long incision from the bottom of the mantle (just above the siphon) to the tip of the mantle. Lift up when cutting to avoid damaging the internal organs. Then cut the muscles attaching the siphon and remove it. Lay both sides of the mantle open, exposing the internal organs.

The **ink sac** looks like a long, thin, silvery fish lying on top of the central mass of organs. Do not cut it open. It is filled with **melanin**, a dark pigment that will stain your skin and clothing. Using tweezers, separate the ink sac from the liver. Gently lift the ink sac while cutting away its connective tissues, then put it into a small container with a little water. Gently rinse your squid with tap-water to remove any ink from the organs. Now cover your squid with a shallow layer of water in the pan, so that the delicate organs and gills are supported by the water—this gives them a more lifelike appearance and you can move them around easier with your probe.

The esophagus runs through the head between the eyes and passes through the liver (a brownish mass of tissue) before reaching the **stomach**. The stomach connects to a transparent, delicate, and baglike **caecum** (*SEEK*-um) that takes up most of the space in the upper half of the mantle cavity. Open the stomach to possibly see tiny bones and scales of fish and/or pieces of crustacean shells. Describe any stomach contents you see:

You may have to rinse your squid again if stomach or liver contents cloud the water. Follow the digestive tract further, identifying the **intestine**, which leads to the **anus**.

Since we know that the squid is an **aerobic**, fast swimmer, what structures are, therefore, necessary to get oxygen from seawater to sustain the animal’s muscle activity?

Look for two white organs that are feathery in appearance and are attached to the sides of the mantle. Cut a small section of tissue from the tip of the structure and examine it under the dissecting microscope. Make a sketch of the tissue in the space below. Notice that the feathery tissue has a huge surface area for maximizing gas exchange. Which two gases diffuse across these gill tissues?

In the circulatory system of mammals, gas exchange structures (lungs) are connected to the motor of circulation (the heart). In the squid, there are 3 hearts. Find a small, flat, clear mass of tissue at the base of a gill. This is one of the 2 **gill hearts** that circulates blood through the gills, where gas exchange takes place. The **systemic heart** receives oxygenated blood from the gills and pumps it to the rest of the body.

Next to the gills on the side of mantle, look for the **stellate ganglion**, a mass of nerve cells that control the muscles of the mantle. How is it associated with swimming?

If you have a female squid, you will see 2 long, white, oval glands lying on top of the internal organs at the posterior end of the mantle cavity (Fig. 4a). These **nidamental glands** secrete an elastic substance that surrounds and protects the eggs (up to several hundred) when they are laid in long, oval capsules. The capsule covering hardens into a rubbery material upon contact with water. The **oviductal gland** is whitish and just to the left of the nidamental glands. It coats the eggs with a gelatinous material. The egg capsules leave the female through her **oviduct**, a flared funnel of tissues extending anteriorly below the left gill. The **ovary** may be very large inside the mantle cavity.

If you have a male squid, the single light-colored **testis** will be behind the **caecum** (Fig. 4b). Sperm produced in the testis are packaged into tiny sacs called **spermatophores** (by the **spermatophoral gland**) on the left side of the mantle, above the left gill heart. The spermatophores travel through the **vas deferens** and are stored in the **spermatophoral sac**, a coiled, rounded mass at the anterior end of the vas deferens. Eventually, the spermatophores exit through the **penis** and are then transferred into the mantle cavity of the female by a specially modified arm on the male, called the **hectocotylus**. Thus, cephalopod eggs are fertilized internally. Look for an arm on the male squid's left side that is slightly different from the other arms. Make a drawing below of the hectocotylus.

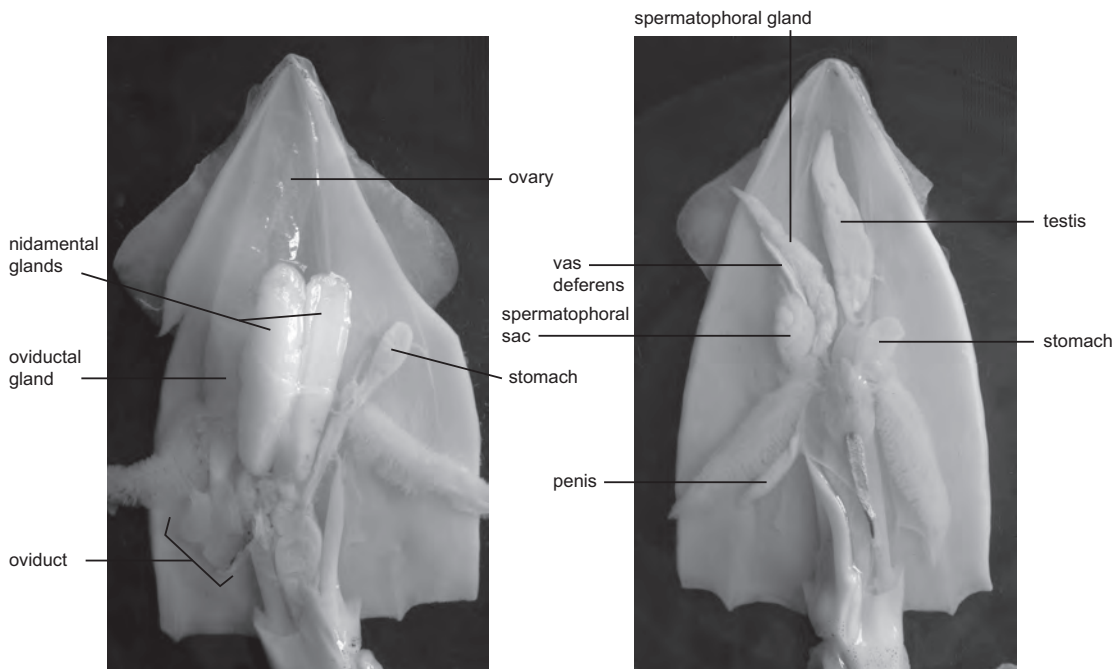


Figure 4. Exposed mantle cavity of a the squid *Loligo opalescens*, showing reproductive organs.
a) Female reproductive organs. b) Male reproductive organs.

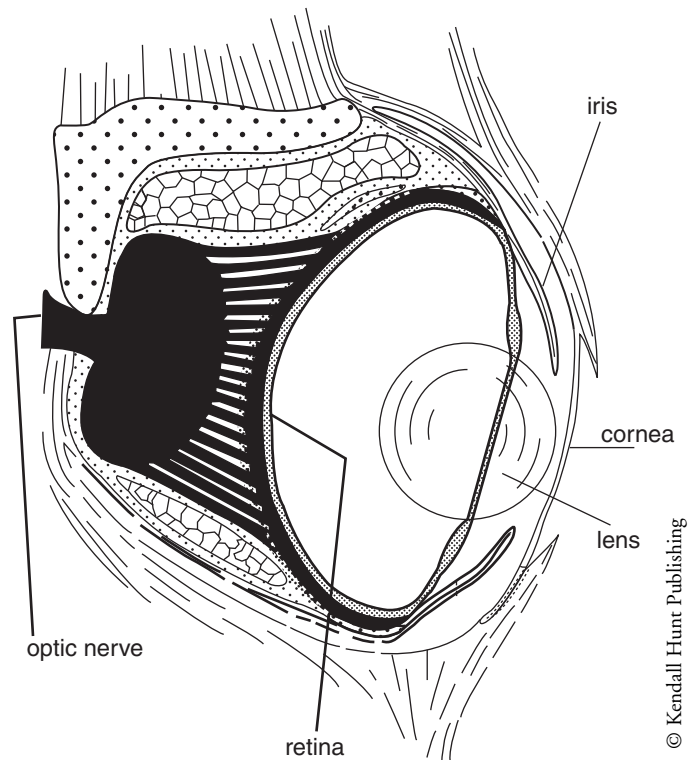
DVD: Squid Congregation

Where does the female squid attach the sacs of fertilized eggs?

What happens to the female after she lays her eggs?

Remove a tiny amount of tissue from the spermatophoral sac, make a wet mount of it on a slide, and look for spermatophores under low power of the compound microscope. Make a drawing of them below:

The eyes of a squid are very similar to our own mammalian eyes (Fig. 5). In proportion to the rest of the body, squids have the largest eyes in the animal kingdom. Consider the size of the squid's eyes and the fact that cephalopods are active predators. Do you think squids have highly developed vision?



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Figure 5. Cross-section view of cephalopod eye.

Remove an eyeball from the head and cut it in half. Look for the **lens**, the **iris** (the colored tissue surrounding the lens), and the **retina** (the inner lining at the back of the eye, which detects light).

What are two key differences between the eyes of a squid and a mammal?

The last step is to remove the pen. Grasp it with forceps and use your scalpel to carefully separate the connective tissues so that you can remove the pen without damaging the organs. The pen should come out in one piece. Puncture the ink sac with the squid's pen. Use the pen to write your initials in squid ink below:

Under what circumstances would a cephalopod release ink?

How does the squid use its ink for survival?

When you have finished all the steps of this dissection, check with your instructor before cleaning your workstation. Complete the following worksheet for this exercise.