# Life in the Fast Lane: From Hunted to Hunter

Lab Activity: Dissection of a Squid-A Cephalopod *Middle School Version*

Lesson by Kevin Goff

Shape of Life

Squid and octopi are **cephalopods** [say "SEFF-uh-luh-pods"]. The name means "head-foot," because these animals have gripping, grasping arms that emerge straight from their heads. At first glance, they seem totally different from every other creature on Earth. But in fact, they are **molluscs**, closely related to snails, slugs, clams, oysters, mussels, and scallops. Like all modern day molluscs, cephalopods descended from simple, snail-like ancestors. These ancient snails crept sluggishly on the seafloor over 500 million years ago. Their shells resembled an umbrella, probably to shield them from the sun's intense ultraviolet radiation. When all sorts of new predators appeared on the scene, with powerful jaws or crushing claws, a thin shell was no match for such weapons. Over time, some snails evolved thicker shells, often coiled and spiky. These heavy shells did a better job of fending off predators, but they came with a price: They were costly to build and a burden to lug around. These snails sacrificed speed for safety.

### VIDEOS TO WATCH

Watch this short clip on the *Shape of Life* website to become familiar with basic mollusc anatomy:

- "Mollusc Animation: Abalone Body Plan" (under Animation; 1.5 min)

Note the abalone's **foot, radula,** and shell-making **mantle.** These were present in the snail-like ancestor of all molluscs

This lifestyle worked fine for many molluscs. And, still today, nearly 90% of all molluscs are heavily armored **gastropods** that crawl around at a snail's pace. Most are grazers or scavengers, a lifestyle that doesn't require speed. About 10% of molluscs – **the bivalves** – have an even less active lifestyle: They are filter feeders who sit still and simply wait for food to come to them. But the remaining 1% of molluscs – the **cephalopods** – have abandoned such lifestyles. They are energetic, active predators who stalk, chase, and kill prey. And they do it not by creeping on the seafloor but by swimming in open water with remarkable speed.

### VIDEOS TO WATCH

Now watch this *Shape of Life* clip:

- "Mollusc Animation: Squid Body Plan"(under Animation; 1.5 min)

Note how the ancestral snail's foot, mantle, shell, body shape, and other traits have radically changed in squid.

Now, it may be hard to imagine snails evolving into sleek and speedy squid, built for hunting on the high seas. It would help if we had a "transitional form" that has traits in between snails and squid. And luckily, we do! The beautiful chambered nautilus has a heavy, coiled shell like a snail. Yet its body is squid-like, with many tentacles and big eyes. These rare "living fossils" give us a glimpse of those early cephalopods that used to swarm the ocean. Some had coiled shells, ranging from the size of a nickel

### VIDEOS TO WATCH

See how the nautilus represents a transition from sluggish snail to speedy swimmer in this *Shape of Life* clip:

- "Mollusc Animation: Nautilus Body Plan" (under Animation; 2.5 min) to bigger than a truck tire! Others' shells were straight cones, sometimes as long as a small airplane! They were able to leave life on the seafloor by storing buoyant gas in their shells, like the living nautilus. In those days, early fish were also slow swimmers, weighed down by heavy, bony plates. But in time, fish lost their bony armor and got much faster. And to keep pace with their fishy competitors, cephalopods evolved bodies built for greater and greater speed, too …as you'll soon see!

In this lab activity you'll dissect *Loligo*, a squid that swims in the open ocean. In this environment, there is nowhere to hide. Success depends on raw speed. Fast, strong, and intelligent, a squid's body is well built for hunting and escaping. They may seem light years away from slow-moving slugs and other brainless gastropods. Yet when you study them closely, you can still see the shadow of snails past.

**YOUR MISSION:** As you dissect your squid, make a running list of as many adaptations for an ***open-water, predatory lifestyle*** as possible. For each, write a sentence describing HOW that trait helps the animal capture, kill, or consume its prey, and/or escape other open water predators. As you do this, keep the ancestral snail in mind. List at least 10 EXTERNAL adaptations and 5 INTERNAL adaptations. Turn these in on a separate sheet of paper.

## EXTERNAL ANATOMY

1. Position your squid in a dissecting tray as diagrammed. ***Make sure the funnel is facing the ceiling!*** Rinsing your specimen under a faucet may help diminish preserving fluid fumes.

2. **Cephalopod** means "head-foot," and for good reason: The tentacles extend straight from the head! Distinguish the head-foot region from the **mantle**. In snails, clams, oysters, mussels, etc., the mantle is a soft, flimsy internal tissue that produces the shell. But the squid lacks an external shell, and its mantle has become thick, muscular, and streamlined, with two **fins**. By flapping its fins, the squid can cruise slowly through the water but it uses its funnel to jet propel when it needs speed. The fins also act as keels for balance and rudders for turning.

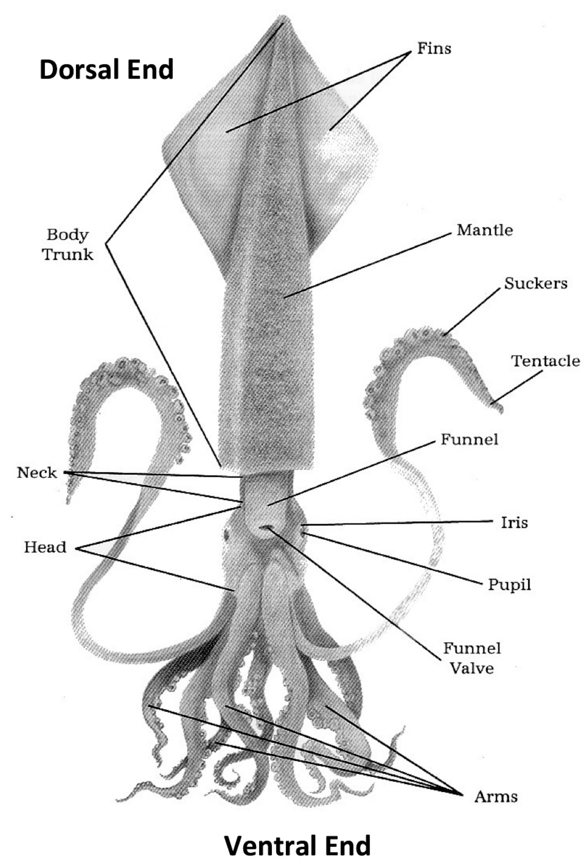


Diagram by Glen Folsom, from David Hall's *An Illustrated Mini Dissection Guide to the Squid*

3. Lift the rim or “collar” of the mantle and peek underneath. This is where water enters the **mantle cavity** and washes over the gills (you’ll see these later). Pry open the nozzle-like **funnel** with forceps or a probe. This is where water is flushed out of the mantle cavity. By inflating and deflating its mantle cavity, the animal can squirt pulses of water from its funnel. (By the way, the funnel is probably all that remains of the ancestral snail’s foot.) The result is fast **jet propulsion**. Squid swim like torpedoes, with the funnel hanging underneath. They can aim the funnel forwards or backwards, allowing them to swim with arms leading the way (for hunting) or arms trailing (for escape).

4. Examine the ten **arms**, whose function is to seize live prey (usually fish). Notice that the two tentacles are longer, and flattened near the tips. Both the arms and tentacles are covered with **suckers**. Snip off a piece of an arm or tentacle and examine the suckers with a magnifying glass or binocular microscope. Look carefully and you’ll see that the suckers have jagged “teeth” for improved grip!

5. Check out the **eyes** on either side of the head. These are advanced “camera” eyes very much like our own, complete with **pupil**, **lens**, and **retina**. (Later you can dissect an eye, but not yet.) Unlike the simple eyes of snails, slugs, and scallops, the cephalopod eye generates crisp images. Indeed, squid and octopi have the keenest eyesight of any invertebrate.

6. Spread the arms and find the squid’s mouth in their midst. Use a probe to poke around inside and you’ll feel the hard, sharp **beak** within. (Later you’ll remove this and dissect it.) The saliva of many cephalopods contains a **venom** that stuns their prey. The small blue-ringed octopus which lives on the coast of Australia packs the most potent venom of all, quite able to kill a human!

7. Notice the dark spots on the mantle. These are **chromatophores** [“crow-MAT-uh-fors”]. These tiny organs enable squid to quickly change color. Each chromatophore is a pool of dark pigment surrounded by muscle fibers and nerves. To turn darker, the squid expands the pools of pigment. To turn lighter it contracts them. Most squid and octopi use camouflage to make up for the absence of a shell. Many octopi can also alter the texture of their skin to mimic rocks, coral, and seaweed! Deep sea squid have glow-in-the-dark **photophores** that create “living light,” or **bioluminescence** [“BYE-oh-loom-uh-NESS-ents”]. Besides the light-producing tissue, these complex little organs are often equipped with shutters, lenses, and internal reflectors, just like a signal beacon. Extraordinary!

### VIDEOS TO WATCH

**For dazzling displays of octopus color-changing and shape-shifting, watch these *Shape of Life* clips (under “Behavior”):**

- **Molluscs: Octopus Camouflage (2 min)**
- **Molluscs: Blue-Ringed Octopus Warning Coloration (1 min)**

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**INTERNAL ANATOMY**

8. Lay your specimen in the dissecting tray, funnel side up. Use scissors (blunt tip down) to make a long cut along the length of the squid's mantle. Start at the funnel and cut to the dorsal tip. Pin the mantle open to reveal the **mantle cavity** and internal organs (see diagram).

   *Valuable dissecting hint:* The organs are held in place by thin, semi-transparent sheets of **mesentery**. By peeling and cutting these membranes away, you can get a much better view of the organs underneath.

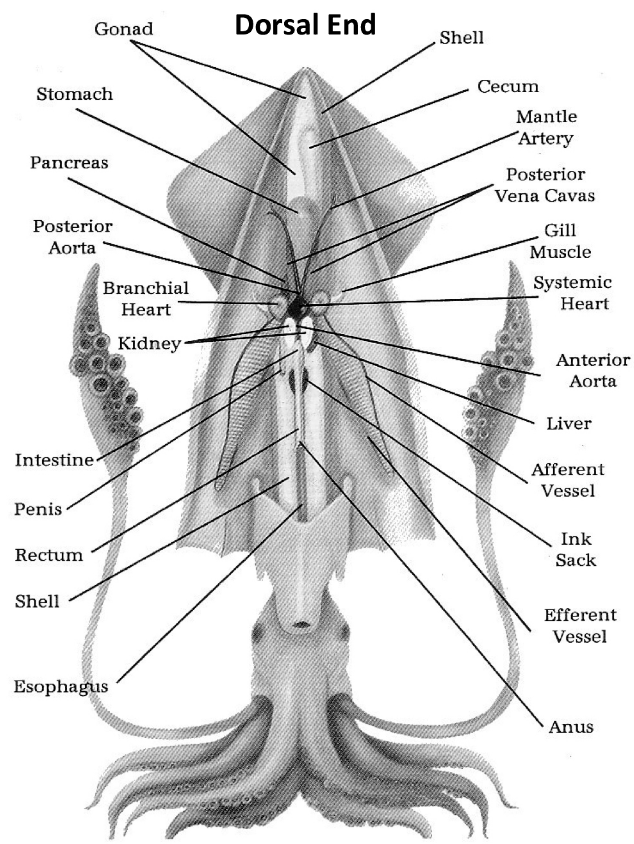


Diagram by Glen Folsom, from David Hall's *An Illustrated Mini Dissection Guide to the Squid*

9. The **gonad** usually occupies the dorsal region of the body cavity. This reproductive organ produces **gametes** (sex cells). Is your squid male, with a smooth, whitish **testis** for producing **sperm**? Or is it female, with an **ovary** and perhaps a mass of orange or yellowish **eggs**? If female, your squid will also have a pair of large, long, cream-colored **nidamental glands** between the gills. These produce the egg casing. During mating, the male uses one of his tentacles to transfer sperm to his mate's mantle cavity. Later, the female expels her fertilized eggs through her funnel. When they hatch, the offspring are already well developed, with eyes, arms, tentacles, color-changing chromatophores, jet propulsion, and all!

10. If your squid is female, you'll want to remove the two large nidamental glands, being careful not to damage the organs underneath. Now explore the two feathery **gills** with a probe. They are much more branched and bushy than the plate-like gills of ancestral snails and most modern molluscs. Moreover, each gill has its own heart! Called **branchial hearts**, they pump blood in and out of the gills to absorb oxygen. In between them is a third heart, the bigger and more muscular **systemic heart**. This pumps oxygen-rich blood to the rest of the body. Squid pipe their blood directly to their tissues through pressurized arteries. This is a major advance over gastropods and bivalves, whose blood just weakly

soaks through the animal's spongy tissues. A squid's blood is colorless until exposed to oxygen, which turns it blue because it's copper-based. (Our own blood is iron-based, which makes it red.)

11. Near the hearts look for a pair of small, triangular, whitish organs: the **kidneys**. These filter nitrogen wastes from the bloodstream and excrete them into the mantle cavity.

12. Identify the digestive organs. Remember that the mouth is in the head, amidst the arms. The **beak** bites off chunks of meat, which travel up the **esophagus** and into the **stomach**. The stomach is just above and behind the hearts, often slightly left of center. It can be hard to find, but if you use your fingertips, it may feel firmer and more muscular than other organs. Slice it open. Two other organs produce digestive **enzymes** to break down food: (1) the **liver**, a long whitish organ against the back wall; and (2) the **pancreas**, which is hard to find because it's small and nestled amidst the kidneys. Nearby is the **cecum**, a big flimsy pouch connected to the stomach. Here food is further digested and nutrients are absorbed into the blood. Undigested food passes down the **intestine** and out the **anus**, to be flushed out through the funnel. This digestive system is more complex than that of grazing gastropods and filter feeding bivalves. It can handle a large mass of food at once and process it quickly.

13. Find the **ink sac** under the intestine. Puncture it with a probe. When threatened, the squid releases clouds of dark, noxious ink to confuse the enemy and screen its escape. Some deep sea squid startle attackers by squirting out glow-in-the-dark ink!

14. Against the back wall you can find the squid's **pen**. This thin, lightweight plate is all that remains of the snail-like ancestor's shell! It's internal now and offers no protection – just a bit of support for the streamlined body. See if you can remove the entire pen without breaking it. Why do you think it was nicknamed a "pen"?

15. Now cut away the squid's arms and carefully remove the **beak**. It's packed in powerful jaw muscles. Strip away the outer tissue and you'll see it resembles a parrot's beak (but upside down). Open the beak to find a toothy tongue – the **radula** ["RADJ-oo-luh"]. Study its hook-like teeth under a magnifying glass or binocular microscope. Can you see how they're arranged for rasping meat off their prey?

16. The squid's **brain** is encased in a "skull" of cartilage between the eyes. It's hard to expose without damaging it, but try slicing at an angle. Squid and octopi have by far the most advanced brains of any invertebrate. It enables them to see crisp images, rapidly react to other animals, and control their arms with great skill. They are capable of learning and can even be trained!

17. Finally, dissect the **eye**. Light enters through the **pupil**, the hole at the front. Around it is an iris that widens and contracts to control brightness. The hard nugget inside is the **lens**, which focuses light on a dark, light-sensitive **retina** at the back of the eye. It's the same design as your own eye, yet the cephalopod eye evolved quite independently of our vertebrate eyes!

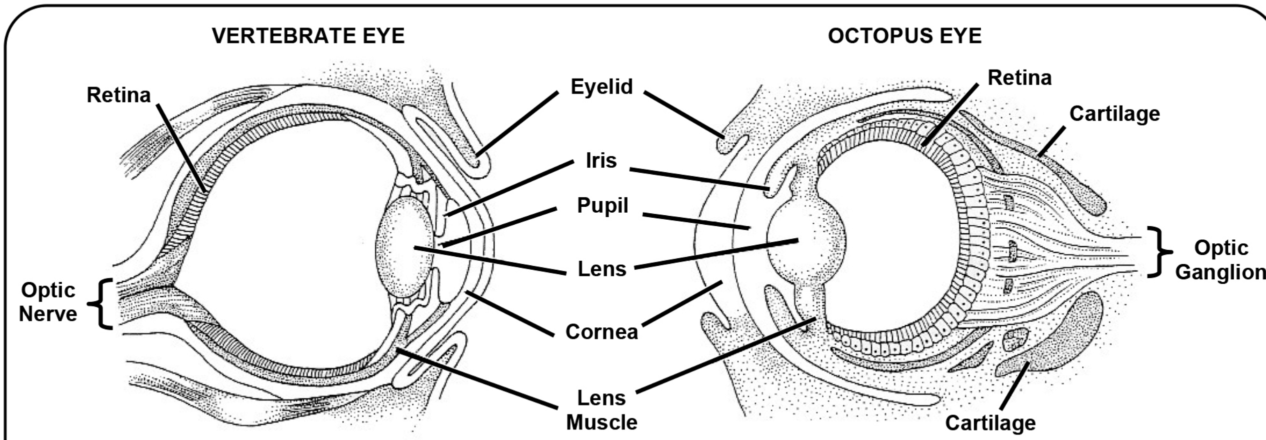

Image: Futuyma's *Evolutionary Biology*, 3rd ed

**POST-LAB ACTIVITIES AND DISCUSSION**

- Share and discuss your list of squid adaptations for a predatory, open water lifestyle.
- Visit the ***Shape of Life*** website and watch one of these two segments:
    - "Peter Ward, Paleontologist: The Ancient Nautilus" (under Scientists; 8 min)
    - "Molluscs: Nautilus Regulates Its Buoyancy" (under Behavior; 2 min)

Discuss with your teacher and classmates how the nautilus represents an evolutionary transition from sluggish snails to speedy squid.

- A "big pattern" that we often see in the fossil record is **co-evolution**. Co-evolution occurs when different plant and animal groups adapt to EACH OTHER, back-and-forth. Very often, this is an "**arms race**" between predators and prey. For example, the rabbit gets faster to outrun the fox, so the fox gets faster in response, so the rabbit gets even faster …and so on. Watch the ***Shape of Life's*** "Molluscs: The Survival Game" (under Phyla; 15 min). Discuss how the 500+ million year history of molluscs exhibits a never-ending co-evolutionary arms race.

- Another "big pattern" is **divergent evolution**. This occurs when one group of organisms splits into NEW and DIFFERENT groups with new habitats and lifestyles. Because the new groups share a common ancestor, they still show some similarities. But they also have differences, because their body parts and behaviors have adapted for new functions. Discuss how the following traits "diverged" during the long history of molluscs:

    - Shells (remember: the ancestral mollusc had a thin umbrella shell on its back)
    - Foot (the ancestral mollusc crawled on a single muscular foot)
    - Gills (the ancestral mollusc had simple plate-like gills)

- The last "big pattern" is **convergent evolution**. It's sort of the opposite of divergent evolution, but not exactly. It occurs when organisms that are NOT closely related evolve SIMILAR body features for similar functions, lifestyles, and habitats. In other words, different groups evolve similar adaptations *separately and independently* of each other. They're alike, but not akin.

  A remarkable example of convergent evolution is the "camera eye" of squid and octopi (see diagram above). It's incredibly similar to the eyes of backboned animals (including us). Yet there are a few telltale differences that show they did NOT evolve from a common ancestor who had a camera eye. The same sophisticated device evolved not once but twice!

  With your classmates, brainstorm examples of NON-molluscs whose traits have "converged" with these other squid traits:

    - Sharp beak
    - Venomous saliva
    - Sleek, streamlined body
    - Supportive inner shell ("pen")
    - Grasping arms