Shape of Life

Squid – Instructor's Guide

Instructor Guide - Middle and High School

Lesson by Kevin Goff

LESSON: Life in the Fast Lane – From Hunted to Hunter

Overview: Lab dissection of a squid, a member of Class Cephalopoda (along with the octopus and nautilus). Supported by several Shape of Life segments, students interpret squid adaptations as a radical case of **divergent evolution**: A line of ancestral snails abandoned the life of sluggish grazing and foraging in favor of a new niche as speedy open water predators. Students will understand that the shelled, but squid-like nautilus, is a "transitional form" en route to the swimming, shell-less cephalopods. Finally, they use the squid to explore another macroevolutionary pattern: **convergent evolution**. Students learn about the remarkable convergence of cephalopod and vertebrate "camera eyes," and are then asked to brainstorm convergences among non-molluscs with the squid's sharp beak, venomous saliva, streamlined shape, supportive inner shell, and grasping tentacles.

Standards: See the list at the end of this document.

Logistics: 75-90 minutes. 2-4 students per team. This lesson can be done as a stand-alone lesson or as part of the Molluscan Macroevolution module. There are separate high school and middle school versions of this lab activity.

Materials:

- ❑ EITHER Preserved squid (*Loligo*, available from biological supply company) or fresh, whole squid from the market. Bigger is better …insist on large specimens when ordering from a biological supply company!
- ❑ Dissecting utensils: trays, scissors, scalpels, forceps, probes, latex gloves, etc.
- ❑ Dissecting scopes or magnifying glasses
- ❑ Computer(s) and projector with internet access

Suggested instructional sequence:

1. Distribute the handout "Life in the Fast Lane: From Hunted to Hunter." The first page conceptually sets the stage for the lab activity to follow. Have students read it and watch the following segments on the

Shape of Life website (http://www.shapeoflife.org/) either as a whole class or on individual computers:

- "Mollusc Animation: Abalone" (1.5 min; on the Animation page)
- "Mollusc Animation: Squid Body Plan" (1.5 min; on the Animation page)
- "Mollusc Animation: Nautilus Body Plan" (2.5 min; on the Animation page)

2. Now have students carry out the dissection following the step-by-step instructions and compiling their lists of open water predatory lifestyle adaptations on a separate sheet of paper. At some point you will also want to show them these two Shape of Life clips (to illustrate chromatophore action):
   - "Molluscs: Octopus Camouflage" (2 min; on the Behavior page)
   - "Molluscs: Blue-Ringed Octopus Warning Coloration" (1 min; on the Behavior page)
3. After the dissection – as a springboard to the final class discussion – show students one of these two Shape of Life segments:
   - "Peter Ward, Paleontologist: The Ancient Nautilus" (8 min; on the Scientists page)
   - "Molluscs: Nautilus Regulates Its Buoyancy" (2 min; on the Behavior page)
4. Closure: Whole-class discussion of the coevolution, divergent evolution and convergent evolution as laid out in Post-lab discussion and questions. The Shape of Life segment "Molluscs: The Survival Game" (under Phyla; 15 min) makes an excellent closure for this unit and for the entire four-lesson mollusc module, nicely reinforcing the macroevolutionary themes of divergence and coevolutionary "arms races" between predators and prey.

Answer key / Notes for post-lab discussion:

- *Share and discuss your list of squid adaptations for a predatory, open water lifestyle.*
- *List at least 10 EXTERNAL adaptations and 5 INTERNAL adaptations. Turn these in on a separate sheet of paper.*

External adaptations

Mantle is muscular for jet propulsion.

Funnel for jet propulsion.

Flexible funnel enables squid to attack with arms leading the way.

Streamlined shape for speed.

Fins for balance, straight tracking, and steering during the hunt.

Ten tentacles for grasping prey.

Suckers for grip on prey.

"Teeth" on suckers for grip.

Well-developed eyes for visual predation.

Mouth located in center of tentacles.

Hard, sharp beak for biting, killing, and tearing prey.

Powerful jaw muscles to strengthen bite.

Venomous saliva to paralyze prey.

Radula to rasp flesh from prey.

Chromatophores for camouflage from prey.

Internal adaptations

Shell is internal to reduce drag.

Shell is lightweight to enhance speed.

Shell is long and slender to support a streamlined body.

Gills are elaborately branched for high surface area, hence O2 absorption, for active hunting.

Three hearts for effective delivery of O2 and carbohydrates to muscles, for active hunting.

Closed circulatory system for efficient delivery of O2 and carbohydrates, for active hunting.

Large stomach and cecum, for handling food in large amounts and in pulses (versus the slow, continuous food intake of grazing gastropods and filter feeding bivalves).

Digestive tract is a sequence of compartments with associated digestive glands, which makes digestion fast and efficient, in support of the high metabolism lifestyle ("burn and earn": burn a lot of calories to earn a lot of calories).

Advanced brain for rapid processing of sensory data and coordination of body (including 10 tentacles) during the hunt.

Discuss with your teacher and classmates how the nautilus represents an evolutionary transition from sluggish snails to speedy squid. *Nautilus as a "transitional form": Retains the soft body and molluscan shell (reminiscent of snails), yet has found a way to leave the seafloor (buoyancy via gas-filled chambers) and to swim (jet propulsion), although nowhere near as fast as squid. Like squid but unlike snails, it has multiple tentacles, although these lack the dexterity of squid and octopi. It also has two large eyes, more advanced than the simple eyes of snails, but not as complex as those of squid and octopi. The nautilus eye is built like a pinhole camera, with a thin pupil that allows seawater to flow into the orb. It lacks the sealed orb of squid and octopi with cornea, lens, and eyelids.*

Discuss the 500+ million year history of molluscs as a never-ending co-evolutionary arms race.

- *Molluscs responded to predatory pressure with changes to their shell, for example leafy hornmouth.*
- *Some evolved the ability to escape by outrunning their enemies, like the abalone escaping from a sea star.*
- *Evolution of new ways of feeding was an element of the arms race: for example,the radula.*
- *The arms race was about eating and avoiding being eaten. One ancient mollusc species evolved the ability to float off the bottom to avoid being eaten: the nautilus' ancestors.*
- *Then some molluscs evolved speed in response to the evolution of fast fish: for example the squid lost their shells to gain speed; and developed mantle muscles, three hearts and jet propulsion.*
- *Squid moved into the deep sea.*
- *Octopus developed intelligence and camouflage.*

Discuss how the following traits "diverged" during the long molluscan history:

- **Shells (remember: the ancestral mollusc had a thin umbrella shell on its back)**

Shell divergences: The umbrella shell of the ancestral mollusc diverged in multiple directions. In gastropods it became coiled and deep to give the soft animal room to withdraw and hide. In bivalves it became a hinged box for safe filter feeding and took on a wedge shape for burrowing. In the nautilus the shell developed gas-filled chambers for buoyancy. In squid it moved inside and became lightweight for faster swimming. In slugs and octopi the shell disappeared altogether.

- **Foot (the ancestral mollusc crawled on a single muscular foot)**

Foot divergences: In predatory moon snails, cone snails, and whelks, the ancestral crawling foot evolved for engulfing prey. In clams it became a backhoe-like organ for burrowing, and in mussels it became a device for putting out anchor lines (byssal threads). In cephalopods all that remains of the foot is the funnel used for jet propulsion. (By the way, the tentacles are not derived from the ancestral foot.)

- **Gills (the ancestral mollusc had simple plate-like gills)**

Gill divergences: In bivalves the simple plate-like gills found in ancestral molluscs became specialized for "cilio-mucoidal" filter feeding. In cephalopods they became branched and bushy for efficient gas exchange to support an active predatory lifestyle.

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

- **Sharp beak**

  Beak convergences: Bird bills, mammal jaws and teeth, turtle beaks, parrotfish teeth, grasshopper mandibles, sea urchin teeth, etc.

- **Venomous saliva**

  Venom convergences: The venomous bite of spiders, snakes, and centipedes; the venomous sting of scorpions, wasps, cone snails, and the Portuguese man-of-war.

- **Sleek, streamlined body**

  Streamlining convergences: The body shape of fish, dolphins, whales, seals, penguins, and countless other swimming animals, as well as birds of flight.

- **Supportive inner shell ("pen")**

  Pen convergences: Vertebrate spines and ribs.

- **Grasping tentacles**

  Tentacle convergences: Crab claws, eagle talons, raccoon paws, primate hands, etc.

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NEXT GENERATION SCIENCE STANDARDS

MS-LS1-4 Use arguments to support an explanation for how characteristic animal behaviors affect the probability of successful reproduction of animals.

MS-LS2-2 Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth.

MS-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

MS-LS4-6 Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors.

HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Cross-Cutting Concept #1: Patterns

Cross-Cutting Concept #6: Structure and Function

Scientific and Engineering Practice #4: Analyzing and Interpreting Data

Scientific and Engineering Practice #7: Engaging in Argument from Evidence

Common Core State Standards for Literacy in Science and Technical Subjects supported in this module:

Writing Standard 1.b, 6-8 Write arguments focused on discipline-specific content

Writing Standard 1.b, 9-10 Write arguments focused on discipline-specific content.

Writing Standard 1.b, 11-12 Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims.

Writing Standard 2, 9-12 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Writing Standard 4, 9-12 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.