Shape of Life

Phylum Mollusca: Shell Shocked

Instructor Guide - Middle and High School

Lesson by Kevin Goff

LESSON The Mussel– A Not-So-Typical Mollusc

Overview: Students study the elaborately whorled, sculpted, and ornamented shells of gastropods not as objects of beauty, but as artifacts born of an evolutionary tradeoff: They are costly to build and carry around, yet essential for survival in a dangerous ocean. The high school version introduces the concept of an evolutionary arms race (coevolution) and reinforces the Darwinian principle of "form follows function." The middle school version emphasizes the concepts of animal adaptation and predator avoidance. In both versions, there is a hands-on activity with shells, and written analysis interpreting the fossil record.

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

Logistics: 45-60 minutes. 2-3 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: An assortment of 8 to 12 gastropod seashells. Try to get a variety of forms. Good specimens include whelks, conchs, cowries, olives, augurs, murexes, turbans, etc. You only need one of each species, as each team can analyze one shell at a time and then exchange it for a new one.

Suggested instructional sequence:

1. Distribute the handout "Shell Shocked" (either the high school or middle school version) and have students read the front page, then carry out the lab activity on the second page. Place seashells in a common area with labels (use common or species name if you know them, or just label them "A" "B", "C", erc.). Each team is to take only one shell at a time, analyze it and record ratings in the data table, and then exchange it for a new shell. Alternatively you can simply have students pass each specimen from one team to the next. Continue until all teams have evaluated all or most of the shell. (Note: Students should wait until after viewing the relevant *Shape of Life* segments – see below – before beginning the data analysis exercise.)
2. After the lab activity, spend a few minutes reviewing results through whole class discussion. Then tell your class that the study of anti-predator seashell designs has been the lifelong obsession of renowned paleontologist Geerat Vermeij of the University of California at Davis. Then show select video segments from The *Shape of Life* website (http://www.shapeoflife.org/):
   - "Geerat Vermeij, Evolutionary Biologist: Reading A Shell's Story" (7.5 min; on the "Scientists" page). This segment nicely develops the theme of predator-prey coadaptations and "arms races," and sets up the student data analysis exercise to follow.
   - "Mollusc Animation: Shell Repair" (1.5 min; on the "Animation" page). A quick piece on how molluscs manufacture and repair their shells.

3. Now have students carry out the data analysis exercise on the Students' Edition of "Shell Shocked," which asks students to interpret four graphs drawn from Vermeij's own research. Afterwards go over their answers via whole class discussion. See below for an interpretation of Vermeij's data.
4. Closure: Show *The Shape of Life* segment "Molluscs: The Survival Game" (15 min; on the "Phyla" page) – an excellent overview of the biology, behavior, and body forms of the main molluscan taxa (gastropods, bivalves, and cephalopods), which reinforces the theme of predator-prey coadaptations and "arms races." You may wish to couple this segment with formal instruction on Phylum Mollusca, depending on your own course objectives.

Answers: Interpretation of Vermeij's Data in "Shell-Shocked"

1. *The first of the four graphs, "Shell-Breaking Predators", shows that predators with an ability to break shells first appeared about 450 million years ago. Since then their numbers have risen, right up to the modern day., Natural selection is clearly favoring traits among predators that enable shell breaking, and so those traits are increasing in frequency. Meanwhile, as the other three graphs show, molluscs are evolving ever better defenses against those shell-breakers. Many gastropods foiled the new predators by developing high spires or narrow apertures. Bivalves and others escaped by heading underground or boring into rocks. And cephalopods either reinforced their shells by coiling them or "sculptured" them with spines and textures to fend off attackers. At the same time, snails with a "weak shell design" have steadily diminished in number. Among prey, then, natural selection is clearly increasing the frequency of traits that protect against shell-breaking predators, while weeding out traits that do not.*

   - ***A side question to discuss with students:*** *Why aren't "weak designs"* completely *weeded out? Probably because there's a cost to making bigger, heavier, more spiny shells. They take lots of calories and chemicals to build. Those are resources that could instead be invested in the production of offspring. Also, such shells probably slow an animal down, forcing it to burn more calories during foraging and diminishing the amount of calories collected for survival and reproduction. It's an evolutionary tradeoff: there are both benefits and drawbacks to the trait.*
   - ***A clarification:*** *Cephalopods seem to vanish from the fossil record about 250 million years ago. Extinction? Sort of, but not exactly. Most cephalopods adopted a new strategy for defense (and hunting): speed. To become faster they reduced and internalized their shells, or discarded them altogether, which is why they are absent from the fossil record. In time, these cephalopods became modern squid and octopods.*

2. *Coevolution occurs when two different groups of organisms mutually influence each other's traits. They perpetually evolve in response to one another. In terms of natural selection, each acts as a "selective pressure" upon the other. It's easy to see here that molluscs have been evolving in response to the ever-increasing threat of shell-breakers, but coevolution implies that the predators are evolving in response to the prey, too. Do we have evidence of this? Yes. Since shell-breakers are increasing in abundance and diversity (number of different taxa), it is clear that shell breaking continues to be a successful way to make a living. So presumably, even as the prey are developing better and better defenses, the predators are successfully evolving new and different ways around those defenses. It's a never-ending arms race, still going on today!*

   However, Vermeij himself has argued that this coevolution is asymmetrical: prey are pressured to evolve specialized adaptations to predators more strongly than predators are pressured to specialize to their prey. Thus the fossil record here does not exhibit the sort of tight, reciprocal, species-specific adaptation that shapes a hummingbird bill to fit its favorite flower – and vice versa. Rather, predator-prey "arms races" are often more of a "diffuse" coevolution in which whole suites of prey adapt in general ways to whole suites of predators, and vice versa. Vermeij dubs this "escalation": prey evolve ever more sophisticated defenses, yet there is no "progress" in it because predators tend to keep pace.

References:

Vermeij, G. J. (1987). *Evolution and escalation: An ecological history of life.* Princeton, NJ: Princeton University Press.

Endler, J. A. (1991). Interactions between predators and prey. In J.R. Krebs & N. B. Davies (Eds.),
Behavioral Ecology: An Evolutionary Approach (3rd ed.). Oxford, UK: Blackwell Scientific.

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NEXT GENERATION SCIENCE STANDARDS

MS-LS1-4 Use argument 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.