

Shape of Life

# Phylum Mollusca: Macroevolution Module

Instructor's Guide

Lesson by Kevin Goff

**Overview:** Through a sequence of engaging laboratory investigations coupled with vivid segments from the acclaimed *Shape of Life* video series, students explore the fascinating structural and behavioral adaptations of modern molluscs. But rather than study these animals merely as interesting in the here-and-now, students learn to view them as products of a 550 million year evolution. Students interpret their diverse adaptations as solutions to the challenges of life in a dangerous world. They use the Phylum Mollusca to understand three major macroevolutionary patterns: divergent evolution, convergent evolution and coevolution.

**Grades:** 7-12. There are high and middle school versions of each lab activity.

**Subjects:** Biology, earth science, ecology, paleontology, evolutionary science

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

## Instructional Approach:

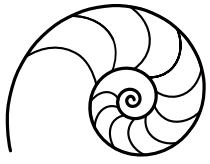
In general, these lessons use an “explore-before-explain” pedagogy, in which students make and interpret observations for themselves as a prelude to formal explanations and the cultivation of key scientific concepts. There are exercises in inquiry and the scientific process using authentic data, where students are pressed to think at higher cognitive levels. Instruction is organized around three unifying themes – the macroevolutionary patterns of divergence, convergence, and coevolution – and students learn to interpret diverse biological examples of these patterns.

## Suggested Lesson Sequence:

This module comprises four lessons. Each is written so that it can **be used either as a stand-alone lesson, or as a piece in a longer unit**. Logistics and other details for each lesson are provided in separate instructor's guides. To do the full unit, follow this sequence:

**1. “Snips and Snails and Gastropod Tails”** – A brief hands-on investigation of Class Gastropoda (snails and slugs), followed by a critical thinking exercise centered on segments of the *Shape of Life*. Students first examine the bodies and behavior of live slugs or snails, then use water balloons to model their unique style of locomotion, and finally tackle a series of analytical questions designed to cultivate an understanding of **divergent evolution**: the branching of a single ancestral form into multiple new forms with diverse new functions, niches, and habitats.

**2. “Shell-Shocked”** – A hands-on investigation of seashell morphology and a data analysis exercise using real data from a *Shape of Life* featured scientist. Students first evaluate real shells for their ability to deter predators. They then watch *Shape of Life* footage highlighting the research of the famous paleontologist Geerat Vermeij, who has been blind since birth and studies fossilized shells with his hands. Finally, students



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examine a handful of Vermeij's graphs showing 500 million years of shell evolution. They use their new insights about shell design to interpret fossil trends as a case of **coevolution**: a relentless "arms race" between molluscs and shell-breaking predators.

**3. "The Oyster: A Not-So-Typical Mollusc"** (or an alternate version: "The Mussel: A Not-So-Typical Mollusc") – a lab dissection of a representative of Class Bivalvia. Supported by several *Shape of Life* segments, students interpret bivalve adaptations as a radical case of **divergent evolution**: A simple ancestral snail with a mobile lifestyle, single dome-shaped shell, bilateral symmetry, and a head ("cephalization") transformed into a headless, double-shelled, sedentary filter-feeder whose bilateral form is no longer obvious.

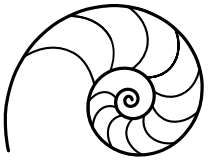
**4. "Life in the Fast Lane: From Hunted to Hunter"** – A lab dissection of a squid, a member of Class Cephalopoda (along with the octopus and nautilus). Supported by several *Shape of Life* segments, students interpret squid adaptations as a radical case of **divergent evolution**: A line of ancestral snails abandoned the life of sluggish grazing and foraging in favor of a new niche as speedy open water predators. 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.

## Intended Learning Outcomes (ILO's)

For summative assessments aligned with these ILO's, scroll to the end of this instructor's guide.

*After these lessons, each student will be able to:*

- Distinguish between gastropods, bivalves, & cephalopods when given examples or distinctive traits of each.
- Match molluscan anatomical traits to their descriptions or functions.
- Explain the adaptive benefit of a cephalized body with bilateral symmetry (as opposed to radial symmetry).
- Describe four evolutionary changes that occurred in the bivalve body – versus the ancestral snail – to suit them for a sedentary, filter-feeding lifestyle.
- Describe a bivalve's "cilio-mucoidal" method of filter feeding.
- List and explain four external and four internal squid adaptations for their predatory, open water lifestyle.
- Interpret new examples of divergent evolution, convergent evolution, or coevolution. Be able to name, explain and make predictions about each macroevolutionary pattern. **Describe their texture. How do you think this helps increase the amount of oxygen absorbed? The increased surface area is for better absorption of O<sub>2</sub> and diffusion of CO<sub>2</sub>.**



### Questions for Assessment

#### 1. Multiple choice: Match animals and characteristics to Mollusc class:

**A:** Class Gastropoda

**B:** Class Bivalvia

**C:** Class Cephalopoda

\_\_\_\_\_ Clams, oysters, scallops, and mussels

\_\_\_\_\_ Squid, octopus, and chambered nautilus

\_\_\_\_\_ Conchs, whelks, cone snails, and sea slugs

\_\_\_\_\_ Jet propulsion

\_\_\_\_\_ Filter-feeders

\_\_\_\_\_ Closed circulatory system

\_\_\_\_\_ Complex, advanced brains and sense organs

#### 2. Match these anatomical traits to the correct descriptions or functions

bilateral symmetry

chromatophore

cephalization

gill

anterior / posterior

heart

dorsal / ventral

open circulation

mantle

closed circulation

mantle cavity

radula

foot

digestive gland

adductor

intestine

hydrostatic skeleton

kidney

funnel

gonad

\_\_\_\_\_ Toothy tongue of gastropods and cephalopods

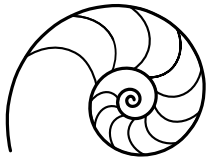
\_\_\_\_\_ Nozzle for jet propulsion

\_\_\_\_\_ Secretes a mollusc's shell

\_\_\_\_\_ Ancestral mollusc's main organ of locomotion

\_\_\_\_\_ Evolution or development of a distinct "head" containing mouth and sense organs

\_\_\_\_\_ Filters nitrogen wastes from the bloodstream



# Phylum Mollusca: Macroevolution Module

## Student Questions

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- \_\_\_\_\_ Muscles create movement by squeezing on fluid-filled spaces within the body
- \_\_\_\_\_ In bilateral animals, the head end versus the tail end
- \_\_\_\_\_ In bilateral animals, the back versus the belly
- \_\_\_\_\_ Space between the mantle and soft body, where water flows across the gills
- \_\_\_\_\_ Gas exchange
- \_\_\_\_\_ Produces gametes (sperm or egg)
- \_\_\_\_\_ Secretes digestive enzymes for the chemical breakdown of food
- \_\_\_\_\_ Blood is piped directly to all tissues in pressurized blood vessels
- \_\_\_\_\_ Blood bathes tissues by soaking into open spaces (“sinuses”)
- \_\_\_\_\_ Transports undigested food away
- \_\_\_\_\_ Body plan in which a single plane of bisection creates mirror image halves
- \_\_\_\_\_ Circular muscle that tightly shuts a bivalve’s two shells
- \_\_\_\_\_ Muscular blood pump
- \_\_\_\_\_ Miniature organ that enables a squid or octopus to change colors

### Short Answer

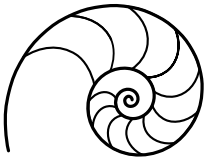
1. The earliest animals on Earth had either asymmetrical bodies or radial symmetry, but many animal lines eventually adopted a **cephalized** body with **bilateral symmetry**. What were the advantages of this new body plan? Explain.

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# Phylum Mollusca: Macroevolution Module

## Student Questions

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### Shape of Life

2. Bivalves evolved from ancestral snails. Describe at least four major changes that occurred to suit them for their sedentary, filter-feeding lifestyle.

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3. Describe a bivalve's "**cilio-mucoidal**" method of filter-feeding.

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4. In contrast to their grazing, scavenging, and filter-feeding cousins, squid are molluscs that have evolved for a life of active hunting in the open ocean. Describe four external and four internal adaptations that cephalopods have (but gastropods and bivalves lack) that are specifically for this predatory open water lifestyle.

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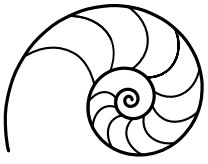
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# Phylum Mollusca: Macroevolution Module

## Student Questions

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### Shape of Life

**5.** Garden snails, snapping turtles, lobsters, armadillos, and the extinct dinosaur Stegosaurus are all animals that evolved a hard, protective covering on their backs, even though they come from very distant phylogenetic lines. What macroevolutionary pattern does this represent?

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**6.** Banana slugs graze on leaves using a rasping radula to rake up plant tissue. Cone snails prey on small fish by harpooning them with a venomous, dart-like radula. The radula of predatory moon snails works like a drill to bore holes through the shells of their victims. The radula of squid is hooked for rasping meat off their prey. What macroevolutionary pattern does this represent? Explain.

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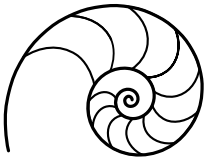
**7.** In the mid-to-late Cenozoic era, many groups of crustaceans (crabs, lobsters, etc.), gastropods, and fish developed the ability to eat molluscs by crushing their shells with powerful claws or jaws, or else by drilling holes in them. In response, molluscs developed thicker shells, often with narrow apertures or high spires, for better defense against predators. Predators in turn became better at breaking shells. And so on. This relentless “arms race” is an example of what macroevolutionary pattern? Explain.

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# Phylum Mollusca: Macroevolution Module

## Student Questions

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### Shape of Life

**8.** For molluscs, mucus is truly a wonderful substance. (If you must know, it's a glycoprotein that creates a colloid in water ...think Jello, only slimier.) Molluscs have modified mucus for dozens of different tasks. Creeping snails lubricate their way with trails of slime. Pteropods or "sea butterflies" are tiny snails that drift on ocean currents, where they capture food with webs of sticky mucus. Sea slugs secrete a noxious slime that is distasteful to predators. Oysters and mussels have sticky gills for harvesting microscopic algae. Limpet snails find their way back home by leaving a mucus trail, rather like Hansel and Gretel and their trail of breadcrumbs. Some sea slugs can safely feed on stinging jellyfish and anemone by coating the stingers with mucus. Which macroevolutionary pattern is this? Explain.

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**9.** A typical hardwood forest is home to many different species of trees, but they all share this trait in common: They are very tall, with their sun-soaking leaves propped up by tall trunks and sprawling branches. Wood is expensive to build and doesn't produce any food, so it seems a bit of a waste. But each species is forced to invest calories in wooden trunks and branches, because otherwise they'd be shaded out by other species – and vice versa. Over evolutionary time, competition for sunlight caused forest plants to grow ever taller simply to keep pace with other plants. What macroevolutionary pattern drove different tree species to such ridiculous heights?

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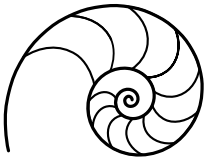
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**10.** Squid and octopi bite their food with a sharp beak. They also stun their prey with venomous saliva. What are some convergences with these two traits elsewhere in the animal kingdom?

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**11.** Imagine a population of average snails that splits in two and migrates to two different habitats. One habitat is rich in food but also abundant with toothy predators. The other habitat is patchy, with food sources few and far between, yet relatively free of predators. Over many generations, how might these two populations diverge?

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**12.** Bats are flying, bug-eating mammals that use echolocation (“sonar”) to navigate at night and home in on prey. If a certain species of bat were to take to an aquatic lifestyle, swimming in the open ocean alongside tuna, sharks, squid, dolphins, and penguins, you might expect it to gradually evolve certain similarities to its swimming brethren. What sorts of convergent evolution might occur?

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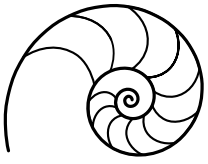
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### Summative Assessment Items (aligned with the unit ILO's above)

*Teacher's edition; applies to student questions - page 1-6*

#### 1. Multiple choice: Match animals and characteristics to correct Molluscan class:

A. Class Gastropoda

B. Class Bivalvia

C. Class Cephalopoda

\_\_\_ [B]\_\_\_ Clams, oysters, scallops, and mussels

\_\_\_ [C]\_\_\_ Squid, octopus, and chambered nautilus

\_\_\_ [A]\_\_\_ Conchs, whelks, cone snails, and sea slugs

\_\_\_ [C]\_\_\_ Jet propulsion

\_\_\_ [B]\_\_\_ Filter feeders

\_\_\_ [C]\_\_\_ Closed circulatory system

\_\_\_ [C]\_\_\_ Complex, advanced brains and sense organs

#### 2. Match these anatomical traits to the correct descriptions or functions

bilateral symmetry

chromatophore

cephalization

gill

anterior / posterior

heart

dorsal / ventral

open circulation

mantle

closed circulation

mantle cavity

radula

foot

digestive gland

adductor

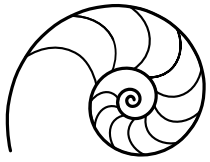
intestine

hydrostatic skeleton

kidney

funnel

gonad



## Shape of Life

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<i>radula</i>	Toothy tongue of gastropods and cephalopods
<i>funnel</i>	Nozzle for jet propulsion
<i>mantle</i>	Secretes a mollusc's shell
<i>foot</i>	Ancestral mollusc's main organ of locomotion
<i>cephalization</i>	Evolution or development of a distinct "head" containing mouth and sense organs
<i>kidney</i>	Filters nitrogen wastes from the bloodstream
<i>hydrostatic skeleton</i>	Muscles create movement by squeezing on fluid-filled spaces within the body
<i>anterior/posterior</i>	In bilateral animals, the head end versus the tail end
<i>dorsal/ventral</i>	In bilateral animals, the back versus the belly
<i>mantle cavity</i>	Space between the mantle and soft body, where water flows across the gills
<i>gill</i>	Gas exchange
<i>gonad</i>	Produces gametes (sperm or egg)
<i>digestive gland</i>	Secretes digestive enzymes for the chemical breakdown of food
<i>closed circulation</i>	Blood is piped directly to all tissues in pressurized blood vessels
<i>open circulation</i>	Blood bathes tissues by soaking into open spaces ("sinuses")
<i>intestine</i>	Transports undigested food away
<i>bilateral symmetry</i>	Body plan in which a single plane of bisection creates mirror image halves
<i>adductor</i>	Circular muscle that tightly shuts a bivalve's two shells
<i>heart</i>	Muscular blood pump
<i>chromatophore</i>	Miniature organ that enables a squid or octopus to change colors

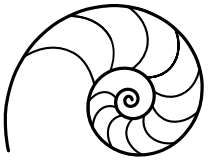
## Short Answer

**1. The earliest animals on Earth had either asymmetrical bodies or radial symmetry, but many animal lines eventually adopted a cephalized body with bilateral symmetry. What were the advantages of this new body plan? Explain.**

*Bilateral symmetry, cephalization, and sense organs clustered in the head foster directional movement in an active search for food (or mates, or habitat). (By contrast, radial symmetry is an adaptation for sessile or slow-moving niches in which the animal waits for food to come to it, such as filter-feeding, or the predation-by-ambush of jellyfish and anemone.)*

**2. Bivalves evolved from ancestral snails. Describe at least four major changes that occurred to suit them for their sedentary, filter-feeding lifestyle.**

*They "decephalized," losing the head and radula of their foraging forebears. The gills evolved for ciliomucoidal feeding. The mantle developed siphons, and the mantle cavity evolved for filter-feeding. The shell became a hinged box, able to open for feeding but shut for protection. Clams evolved wedge-shaped shells and a backhoe-like foot for burrowing. The mussel's foot became a device for putting out anchor lines (byssal threads). Oysters and scallops abandoned bilateral symmetry in favor of a body form able to lie on one flank.*



### 3. Describe a bivalve's "cilio-mucoidal" method of filter-feeding.

*Sticky mucus on gills traps food particles. Cilia then carry food particles through channels to the palps that sort particles, and direct the food ultimately into the mouth.*

### 4. In contrast to their grazing, scavenging, and filter-feeding cousins, squid are molluscs that have evolved for a life of active hunting in the open ocean. Describe four external and four internal adaptations that cephalopods have (but gastropods and bivalves lack) that are specifically for this predatory, open water lifestyle.

*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.*

*Eight arms and two 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*

*Internal adaptations*

*Shell is internal to reduce drag.*

*Shell is lightweight to enhance speed.*

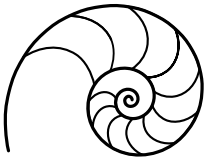
*Shell is long and slender to support a streamlined body.*

*Gills are elaborately branched for high surface area, hence more oxygen absorption, for active hunting.*

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

*Closed circulatory system for efficient delivery of oxygen 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).*



5. Garden snails, snapping turtles, lobsters, armadillos, and the extinct dinosaur Stegosaurus are all animals that evolved a hard, protective covering on their backs, even though they come from very distant phylogenetic lines. What macroevolutionary pattern does this represent? Explain.

*Convergent evolution. These species are only distantly related yet independently evolved a similar trait for a similar function.*

6. Banana slugs graze on leaves using a rasping radula to rake up plant tissue. Cone snails prey on small fish by harpooning them with a venomous, dart-like radula. The radula of predatory moon snails works like a drill to bore holes through the shells of their victims. The radula of squid is hooked for rasping meat off their prey. What macroevolutionary pattern does this represent? Explain.

*Divergent evolution. All four species are molluscs, sharing a common ancestor, but that ancestor's radula has been modified for new functions and new niches.*

7. In the Paleozoic era, molluscs protected their soft, vulnerable bodies with a hard shell. Then in the mid-to-late Cenozoic era, many groups of crustaceans (crabs, lobsters, etc.), and fish developed the ability to eat molluscs by crushing their shells with powerful claws or jaws; some gastropods developed the ability to drill holes in them. In response, molluscs developed thicker shells, often with narrow apertures or high spires, for better defense against predators. Predators in turn became better at breaking shells. And so on. This relentless "arms race" is an example of what macroevolutionary pattern? Explain.

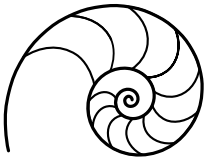
*Coevolution. Predators and prey are reciprocally adapting to each other.*

8. For molluscs, mucus is truly a wonderful substance. (If you must know, it's a glycoprotein that creates a colloid in water ...think Jello, only slimier.) Molluscs have modified mucus for dozens of different tasks. Creeping snails lubricate their way with trails of slime. Pteropods or "sea butterflies" are tiny snails that drift on ocean currents, where they capture food with webs of sticky mucus. Sea slugs secrete a noxious slime that is distasteful to predators. Oysters and mussels have sticky gills for harvesting microscopic algae. Limpet snails find their way back home by leaving a mucus trail, rather like Hansel and Gretel and their trail of breadcrumbs. Some sea slugs can safely feed on stinging jellyfish and anemones by coating the stingers with mucus. Which macroevolutionary pattern is this? Explain.

*Divergent evolution. These are all closely related molluscs that have evolved mucus for diverse new functions.*

9. A typical hardwood forest is home to many different species of trees, but they all share this trait in common: They are very tall, with their sun-soaking leaves propped up by tall trunks and sprawling branches. Wood is expensive to build and doesn't produce any food, so it seems a bit of a waste. But each species is forced to invest calories in wooden trunks and branches, because otherwise they'd be shaded out by other species – and vice versa. Over evolutionary time, competition for sunlight caused forest plants to grow ever taller simply to keep pace with other plants. What macroevolutionary pattern drove different tree species to such ridiculous heights?

*Coevolution. The different species adapted to one another reciprocally – an arms race that prevents them from saving calories by building shorter bodies. (This is not convergence, because all the trees descended from a common woody ancestor.)*



**10. Squid and octopi bite their food with a sharp beak. They also stun their prey with venomous saliva. What are some convergences with these two traits elsewhere in the animal kingdom?**

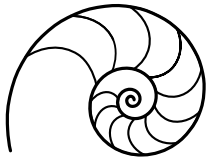
*Bird bills, mammal jaws and teeth, turtle beaks, parrotfish teeth, grasshopper mandibles, sea urchin teeth, etc. The venomous bite of spiders, snakes, and centipedes; the venomous sting of scorpions, wasps, cone snails, and the Portuguese man-of-war.*

**11. Imagine a population of average snails that splits in two and migrates to two different habitats. One habitat is rich in food but also abundant with toothy predators. The other habitat is patchy, with food sources few and far between, yet relatively free of predators. Over many generations, how might these two populations diverge?**

*The first population might evolve heavier, more sculptured shells and slower locomotion, while the second population might evolve thinner shells or even lose their shells altogether, while becoming more mobile. The first might evolve for burrowing while the second might evolve for swimming.*

**12. Bats are flying, bug-eating mammals that use echolocation (“sonar”) to navigate at night and home in on prey. If a certain species of bat were to take up an aquatic lifestyle, swimming in the open ocean alongside tuna, sharks, squid, dolphins, and penguins, you might expect it to gradually evolve certain similarities to its swimming brethren. What sorts of convergent evolution might occur?**

The bat body might become even more streamlined. Wings might shorten and become robust enough to serve as fins/flippers. The stubby tail might broaden into a tailfin for propulsion. Fur might fall out, making the skin smooth and sleek. Echolocation might become more like that of dolphins and whales, with pitches appropriate for traveling through sea water.



### 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.
- MS-ESS1-4** Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.
- 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: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- 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.

### Common Core State Standards for Mathematics supported in this module:

**8.SPA.1 Statistics & Probability** – Investigate patterns of association in bivariate data: Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities.

**HSS.ID.B.6 Statistics & Probability** – Interpreting Categorical and Quantitative Data: Summarize, represent, and interpret data on two categorical and quantitative variables.

**HSS.IC.B Statistics & Probability** – Making Inferences & Justifying Conclusions: Make inferences and justify conclusions from sample surveys, experiments, and observational studies.