

Marine Arthropod Adaptations + Engineering Design

Successful Arthropod Structures, Behaviors and Inspiration for Innovation

Overview

Students explore the extraordinary adaptations and diversity of marine arthropods through short Shape of Life videos and student-centered activities in the 5E Instructional Model. Options to engage students include showing a short clip of an interesting marine arthropod phenomenon with the audio muted. Then students identify the structures of all arthropods with the support of one or more video segments. Students will record notes about physical and behavioral adaptations, then create a diagram of their favorite marine arthropod species, labeling its structures and adding annotations to describe their functions. Possible Enrich / Extend activities are listed at the end of the lesson, including a design thinking / biomimicry / engineering activity inspired by arthropod adaptations, a comparison activity, and field studies to investigate the arthropods in nearby natural areas—or even the supermarket.

Objectives

- Students will describe marine arthropod adaptations orally and in writing.
- Students will create labeled diagrams of a marine arthropod species of their choice.
- If the design process / engineering extension is completed, students will develop and construct a design for a useful invention inspired by one or more arthropod adaptations.
- If the comparison extension is completed, students will compare adaptations of a marine arthropod species to those of another animal.

Subjects

Science, Environmental Education, Writing, and Art

Grades 6–12

Time

45–90 minutes

Vocabulary

Adaptations, antennae, appendage, Arachnida/arachnid, arthropod, chitin, Crustacea/crustacean, evolution, exoskeleton, genetic variation, gills, hydrothermal vent, Insecta/insect, larva, marine, molting, Myriapoda/myriadpod, natural selection, niche, predator, segmented, terrestrial



A hermit crab in its camouflaged shell

Standards		Middle School / High School
Next Generation Science Standards 	Performance Expectations	MS-LS1-3: Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories. MS-LS3-2: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. 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. HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
	Disciplinary Core Ideas	LS1: From Molecules to Organisms: Structures and Processes LS1.A: Structure and Function LS1.B: Growth and Development of Organisms LS4: Biological Evolution: Unity and Diversity LS4.C: Adaptation
	Crosscutting Concepts	• Cause and Effect • Structure and Function • Systems and System Models
	Science & Engineering Practices	• Developing and Using Models • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information
Common Core ELA 	Writing	7
	Speaking & Listening	4, 6
	Language Standards	1, 2, 3, 6

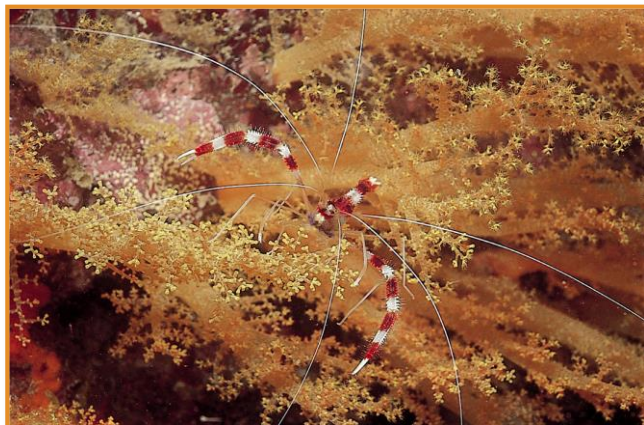
Teacher Background

Phylum **Arthropoda** contains by far the largest number of species on Earth—over one million of the roughly one-and-a-quarter million named animal species. And the phylum may contain more than 30 million species, according to the University of Michigan Museum of Paleontology, accounting for over 85% of known animal species.

Where They Live

During the Cambrian Explosion 540 million years ago Arthropods first evolved and diversified. They are the most abundant group of animals in the ocean, living in all habitats from the intertidal to deep sea hydrothermal vents.

A banded coral shrimp



Body Plan

The key to the incredible diversity and success of arthropods in the ocean is their very adaptable **body plan**. The segmentation of both their body and appendages opened the door for the evolution of their body having many parts and many types of appendages. In primitive arthropods, each segment had an appendage. Today, marine arthropods have many diverse appendages—antennae, claws, walking legs, and mouthparts.

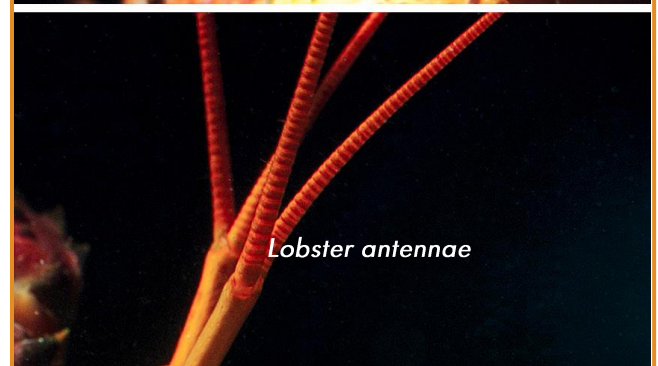
Body Structures

The name arthropod means “jointed foot” in Greek, and their **jointed appendages** have been a key part of their success. Despite their myriad shapes and behaviors, all arthropods have the important structures listed below in common.

- **Segmented body**
 - All arthropod bodies are divided into segments.
 - In most, the segments are grouped into three functional units: the **head, thorax, and abdomen**. However, some such as **crustaceans** (including crabs, lobsters, shrimp, and horseshoe crabs) have a **cephalothorax**, which is a fused head and thorax.
 - Many pairs of limbs: Usually each segment has a pair of appendages and the appendages have diversified uses. Primitive arthropods called trilobites were primarily detritus feeders on the seafloor, but they are also thought to have been top predators in the sea for more than 325 million years. Their reign began in the Cambrian period when their primitive legs, complex armored bodies, and the first true eyes in the animal kingdom gave them immense power over less-endowed prey.
 - The segmented body is a powerful arthropod evolutionary tool that is common elsewhere in the animal kingdom. People are segmented, too, though not as obviously as earthworms or lobsters, and you have to know how to look at our spine and muscles to see the segmentation. This kind of construction allows a body to build itself in identical segmented units that become specialized for particular functions. Many of the tasks of arthropod living, like eating or sensing the world are handled by appendages attached to each segment of the body or the head of an arthropod.
- **Jointed Appendages**
 - Possess numerous **jointed appendages**, such as legs
 - Jointed legs allow flexibility and range of motion; can work as shock absorbers
 - Controlled by tendons and powerful muscles



A lobster's body is grouped into the cephalothorax, upon which the legs are attached and most of the internal organs are housed, and the abdomen, which is primarily used for swimming and escaping predators. Females also carry their eggs beneath their abdomens.



- These appendages are segmented, which makes them both flexible and easily adapted to become antennae, claws, jaws, and other mouth parts, and especially legs—for walking, clinging, swimming, holding onto egg sacs, digging, etc. Sections of the legs even evolved into **gills** for obtaining oxygen from the surrounding seawater. Most marine arthropods have gills.
- Evolution allowed them to be modified for specialized functions, such as sensing, feeding, defense, and swimming (**antennae**, claws, mouthparts, swimmerets and tail fans of crayfish and lobsters, reproductive organs, eyes on stalks, etc.)
- **Exoskeleton**
 - A jointed protective armor, called an **exoskeleton**, covers the body
 - Hard exoskeleton made mostly of **chitin** and protein, sometimes made harder by calcium carbonate
 - Supports body
 - Provides protection like armor
 - Prevents water loss
 - Molting. Think of a crab's shell. An arthropod regularly sheds its exoskeleton; the growing body cracks it open and sheds it. Then it expands its body before the new exoskeleton hardens. This process is called **molting**. An arthropod must molt to grow. The new exoskeleton is soft immediately after molting, making the animal vulnerable to predation, but it hardens in a couple of days.
 - Their body parts and muscles attach to the inside of this armor. It provides a framed support that the muscles can attach to.
- **Bilateral Symmetry**
 - Same on left and right sides of body. Though lots of other animals including humans are bilaterally symmetrical, the arthropods with their segmented bodies and many appendages epitomize this trait.
 - Differs from radial symmetry of organisms like coral polyps

Life Cycle

All marine arthropods begin life as eggs, with the majority of species then entering a juvenile **larval** stage, which is usually quite different from the adult stage (and incapable of reproduction.) This is known as a **complete metamorphosis** between life stages. Larvae of many arthropod species are tiny **plankton** in the ocean, carried by currents until they settle out. Learn more on the "Nauplii Larvae" page:

shapeoflife.org/news/featured-creature/2018/05/16/nauplii-larvae. The video "Embryos and Larvae" from Plankton Chronicles provides excellent magnified visuals (up to 00:35) of crustacean larvae: planktonchronicles.org/en/episode/embryos-and-larvae. UC Berkeley provides additional details on their "Crustaceamorphia: Metamorphosis and Larvae" page: ucmp.berkeley.edu/arthropoda/crustacea/metamorphosis.html.

Some species, such as lobsters, emerge from eggs as simply smaller versions of their adult forms. They go



Larval, free-swimming stage of a crab at 120x magnification; Immature forms of countless species play critical roles in marine food webs, and many of them being impacted by climate change and ocean acidification.

Creative Commons image shared by heirs of Josef Reischig:
[commons.wikimedia.org/wiki/File:Crab_larva_\(265_08\).jpg](https://commons.wikimedia.org/wiki/File:Crab_larva_(265_08).jpg)

through a number of molts before reaching their adult, sexually mature form, but they are otherwise indistinguishable from the immature forms. This is known as an **incomplete metamorphosis**

Horseshoe crabs (*Limulus polyphemus*) are an interesting case—chelicerates (see below) which are thought to have been among the first arthropods to venture from the ocean. They lay their eggs on the shore but the young must return to the ocean as soon as they hatch. Interestingly, their blood is invaluable to medical research, but their numbers are declining (Krisfalusi-Gannon et al.). Learn more with this Shape of Life feature: shapeoflife.org/news/featured-creature/2017/05/19/horseshoe-crab-limulus-polyphemus.

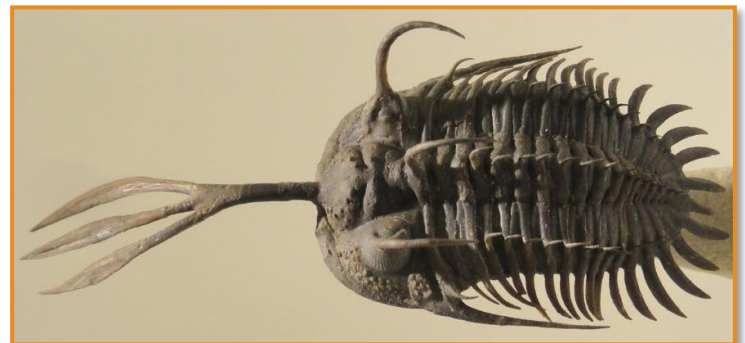
Classification

Animals of the phylum **Arthropoda** possess an almost incomprehensible variety of body shapes and ways of living. The 5 main groups are:

- **Crustaceans** (subphylum **Crustacea**) includes some of the most prized (and expensive) human foods, such as lobsters, king crabs (12-foot leg span!), and shrimp.
- **Chelicerates** include **arachnids** (class **Arachnida**, such as spiders and disease-carrying parasites, such as ticks), as well as sea spiders, scorpions, and horseshoe crabs, which may be aquatic arachnids according to a 2019 molecular analysis published by Ballesteros and Sharma in *Systematic Biology*: doi.org/10.1093/sysbio/syz011.
- **Trilobites**: An extinct group of arthropods that are found in the fossil record from about 521 million years ago until the mass extinction that occurred about 252 million years ago. They were a diverse group that included scavengers, predators, and filter feeders. Learn more on the Trilobita page from UC Berkeley: <https://ucmp.berkeley.edu/arthropoda/trilobita/trilobitalh.html>.
- **Insects** (class **Insecta**) comprise over 75% of all known animal species alone. Their **biodiversity** around the world on every continent (including Antarctica) is astounding, from large flying dragonflies to microscopic animals found in soil.
- **Myriadpods** include millipedes and centipedes. See “Arthropod Animation: Millipede Breathing Tubes” (0:59) for a fascinating glimpse into to their bodies and how they became adapted to breathe air: shapeoflife.org/video/arthropod-animation-millipede-breathing-tubes.



Public domain image by Breese Greg, U.S. Fish & Wildlife Service
commons.wikimedia.org/wiki/File:Limulus_polyphemus_horseshoe_crab_on_coast.jpg



Walliserops were trilobites that had trident-like appendages

Creative Commons image by Daderot:
commons.wikimedia.org/wiki/File:Walliserops_trifurcatus_Early_Devonian_Timrhahart_Formation_Ibe_I_Gara_el_Zguilma_Draa_Valley_Morocco_-_Houston_Museum_of_Natural_Science_-_DSC01584.JPG

Materials + Preparation

- Shape of Life video “Marine Arthropods: A Successful Design” (9:28): shapeoflife.org/video/marine-arthropods-successful-design
Decide if you will show the video to the whole class and/or have partners view the video while taking notes about arthropod adaptations and/or sketching them.
- Other short videos that can be incorporated into the lesson as Engage phenomena, to illustrate key concepts in the Explain section, or as part of Enrich / Extend activities are available at shapeoflife.org/arthropod:
 - “Arthropod Animation: Swiss Army Knife” (0:52): shapeoflife.org/video/arthropod-animation-swiss-army-knife
 - “Arthropods: Blue Crab Molting” (2:24): shapeoflife.org/video/arthropods-blue-crab-molting
 - “Arthropods: Horseshoe Crab” (1:24): shapeoflife.org/video/arthropods-horseshoe-crab
 - “Arthropod Locomotion: Engineering” (7:15): shapeoflife.org/video/arthropod-locomotion-engineering
 - “Bill Shear, Biologist: How Arthropods Left the Sea” (6:38): shapeoflife.org/video/bill-shear-biologist-how-arthropods-left-sea
 - “Marine Arthropod Animation: Body Plan” (1:41): shapeoflife.org/video/marine-arthropod-animation-body-plan
 - “Paleontology: New Evidence Revises Thinking, Anomalocaris” (4:09): shapeoflife.org/video/paleontology-new-evidence-revises-thinking-anomalocaris
- Computer with Internet connection and data projector if you plan to show all or part of the video to the whole class
- Science notebook and pencil or pen for each student
- Whiteboard or chart paper and markers
- *Optional*: Colored pencils and/or markers for students to share



Scene from “Marine Arthropods: A Successful Design”

Teaching Suggestions in the 5E Model

Engage

1. Options to “hook” students and introduce the lesson. (2–5 min.)

- Show students the short video with the sound muted, “Arthropods: Blue Crab Molting” (2:24): shapeoflife.org/video/arthropods-blue-crab-molting. You might start the clip at 1:30 and show it to the end. Then ask students to:
 - Explain the phenomenon.
 - Think about what group of animals they think has spread to the most places on Earth and why. This could include in saltwater, freshwater, on land, and even flying in the air.
- Give the students a minute to brainstorm ideas with a partner, then ask the groups to share their ideas with the whole class and discuss.
- Tell the students that today they will be learning about the organisms that comprise over 85% of known animal species, and over 75% of all known living organisms of any type—**arthropods**.
- Ask the students to complete the “Marine Arthropod Trivia” activity at the end of the lesson to see what they already know about the phylum and prime them for the lesson. You could also ask them to try to answer trivia questions orally (with or without a partner).



Blue crab as it finishes molting and emerges from its old shell

Explore

2. Students watch “Marine Arthropods: A Successful Design” and consider arthropod adaptations. (20 min.)

- Depending on how many computers and/or other devices your students have access to, consider asking them to watch “Marine Arthropods” (9:28) with a partner while thinking about the **adaptations** that help the arthropods survive. They should record notes about the physical adaptations (body structures) and behavioral adaptations (things the organisms do) that help them to survive, including simple sketches of the organisms and their important structures. They might also add arrows or other symbols to indicate movements and other processes. Consider giving them a choice between recording notes in science notebooks and a digital format.
- Encourage students to turn on closed captioning using the CC button so they can read along with the video. Students can also use headphones, if available, to better hear the narration and minimize distractions from other groups.
- Circulate through students, answering questions and providing feedback, as necessary.



Explain

3. Discuss important concepts and terms with students. (4–15 min.)

- Gather students together and briefly discuss their ideas about marine arthropod adaptations—structures, as well as behaviors.
- Discuss important concepts explained in the Teacher Background section, writing them on the board and asking students to take notes on them in science notebooks. Use the short videos on the Shape of Life website as visual aids, such as “Arthropod Locomotion: Engineering” (7:15): shapeoflife.org/video/arthropod-locomotion-engineering.
- Explain that the name Arthropoda means “jointed foot” in Greek. Do students think that name was a good choice for this phylum of animals? Why or why not?
- Discuss how despite their myriad shapes and behaviors, all animals in the phylum **Arthropoda** have certain important structures in common:

- **Segmented body**

Discuss with support of clip such as “Marine Arthropod Animation: Body Plan” (1:41):

shapeoflife.org/video/marine-arthropod-animation-body-plan

- Body divided into segments
- Usually grouped into larger functional units (such as cephalothorax and abdomen)

- **Jointed legs**

Explain that all arthropods have many pairs of jointed limbs. Ask students to explain why that adaptation has been so helpful for their incredible success.

- Increased flexibility, range of motion, and shock absorption
- Animal lower to ground to improve stability; lower center of gravity
- Steps in the **evolution** of arthropods to better fill specific **niches** in the environment—via **natural selection** and **genetic variation**—allowed new uses for their jointed appendages: **antennae**, claws, wings, mouth parts, etc.

You might show the short clip “Marine Arthropod Animation: Body Plan” (1:41) with the audio muted and ask student volunteers to explain what is happening using the correct terms: shapeoflife.org/video/marine-arthropod-animation-body-plan

- **Exoskeleton**

Discuss student ideas about the benefits and drawbacks of an exoskeleton. Use a visual aide such as “Arthropods: Blue Crab Molting” (2:24): shapeoflife.org/video/arthropods-blue-crab-molting.



- Hard exoskeleton supports body and provides protection like armor; made mostly of **chitin** and protein, sometimes made harder by calcium carbonate
- Prevents water loss
- Gives a surface for muscle attachment
- **Molting:**
 - Growing body cracks open exoskeleton to shed it and grow larger; new exoskeleton is soft immediately after molting, making them vulnerable to predation
 - Softer, new skeleton inflates quickly to larger size and hardens in a couple days
 - Must molt to grow
- Ask students to compare an exoskeleton to the **endoskeleton** found in us humans and other chordates. What are the advantages and disadvantages of each?

- **Bilateral symmetry**

- Same on left and right sides of body
- Differs from radial symmetry of organisms like coral polyps

- Discuss the arthropod **life cycle**. The majority of species emerge from eggs in a juvenile **larval** stage. Arthropod larvae are usually quite different from the adult stage and incapable of reproduction. Show students the video “Embryos and Larvae” from the Plankton Chronicles (up to 00:35) as a visual aide:

planktonchronicles.org/en/episode/embryos-and-larvae.

- Discuss how the larvae of many arthropod species are tiny **plankton** in the ocean, carried by currents until they settle out. You might print copies of the “Nauplii Larvae” page and ask students to read it with a partner and reflect of their important role in ocean ecosystems in science notebooks: shapeoflife.org/news/featured-creature/2018/05/16/nauplii-larvae.



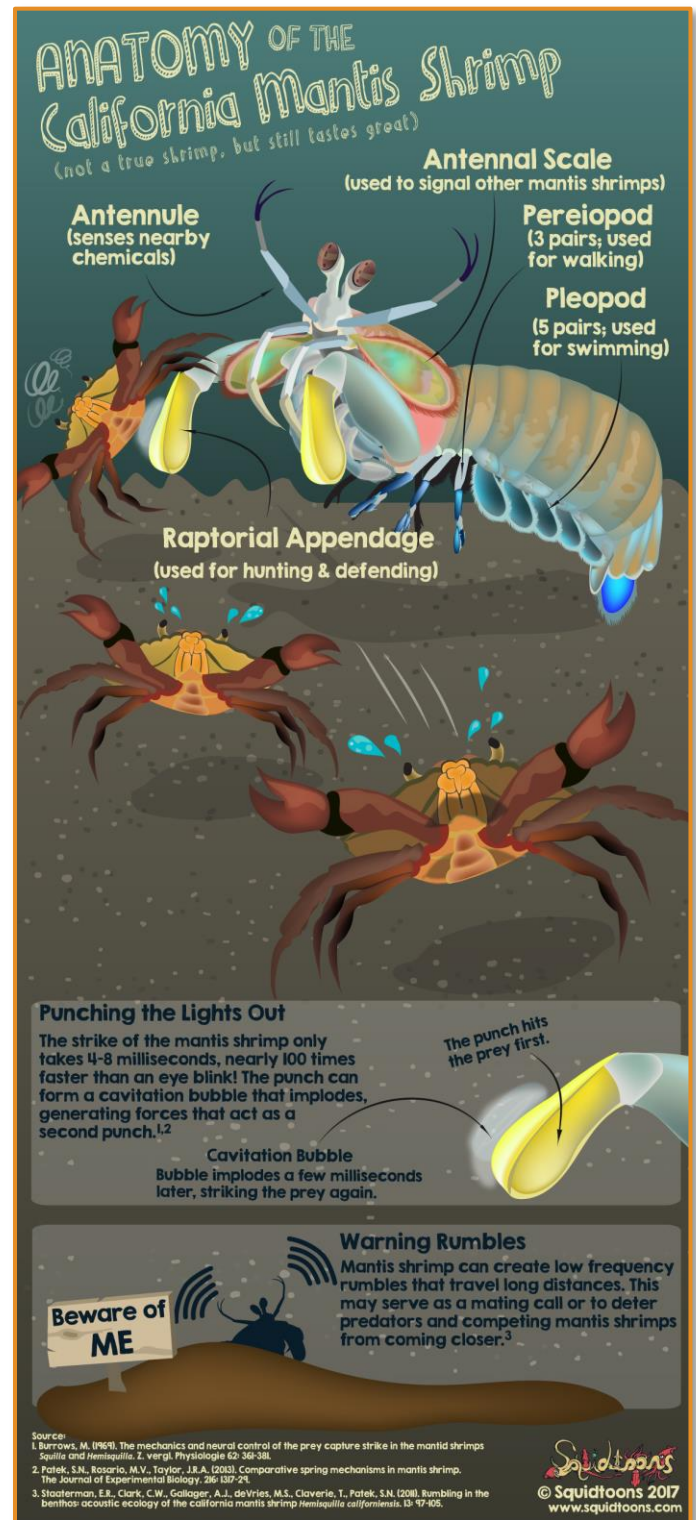
A crustacea nauplius larva

4. Discuss how understanding arthropod structures and their functions helps us understand the evolution of animal adaptations. (2–10 min.)

- Ask students to reflect on how arthropod adaptations, such as jointed appendages, help to explain the evolution of animals. (For example, jointed appendages evolved into different structures, such as antennae and mouth parts, to help them adapt to particular environmental niches.) This can first be done as a think-pair-share activity before discussing it as a class.
- Relate the important concept of cause and effect to your discussion. For example, talk about how their central nervous system transmits messages between the muscle cells, causing them to contract. In the case of marine arthropods, this process can result in very fast movements and powerful snapping claws.
- *Optional:* You might also discuss how **natural selection** of species through competitive pressures can result in the long-term effects of evolutionary changes over time. What might have caused the further evolution of marine arthropods to create those structures found in modern animals, such as chelae (claws)?

5. Students create a detailed model of a marine arthropod. (20 min.)

- Ask students to make a detailed scientific sketch, 3-D model, or computer-generated diagram of their favorite arthropod species, such as a crab or a shrimp, labeling the individual structures and their functions. You might also provide options to create a robot based on a marine arthropod or an ancient arthropod form, such as a trilobite. Share one or more exemplars that you and/or a student created, and/or these fun graphics/posters from Squidtoons:
 - “Anatomy of the California Mantis Shrimp”: squidtoons.com/portfolio-item/anatomy-of-the-mantis-shrimp
 - “Anatomy of the Horseshoe Crab”: squidtoons.com/portfolio-item/anatomy-of-the-horseshoe-crab
 - “Anatomy of the Tuna Crab”: squidtoons.com/portfolio-item/anatomy-of-the-tuna-crab
 - “Anatomy of the Yeti Crab”: squidtoons.com/portfolio-item/anatomy-of-the-yeti-crab
- The models could show only external structures, or you might encourage advanced students to include some internal anatomy, too.
- Students should be encouraged to add labels and annotations (more detailed explanations of the features of the diagrams). They can also color their diagrams and explain them in writing, including the adaptations that help the organisms to survive.
- Diagrams can be completed with the support of reference materials such as books and reputable sources on the Internet.



“Anatomy of the California Mantis Shrimp”
from Squidtoons: squidtoons.com/portfolio-item/anatomy-of-the-mantis-shrimp

Evaluate

6. Students can present their diagrams, comparisons, and/or other projects to the class.

- Provide a rubric such as the one at the end of the lesson so students know how they will be assessed.
- Help guide students to “use argument supported by evidence” that explains how their organisms “are a system of interacting subsystems composed of groups of cells” (NGSS).
- Students could also be asked to create a larger version of their diagram on poster board with more detail, color, etc. These can include clear annotations which could also serve as notes if you would like students to present their diagrams to the class.
- Completed projects can also be displayed on classroom and/or school walls.

7. Review completed student diagrams and science notebooks.

- Review student diagrams, labels, and annotations.
- Check that they have explained marine arthropod structural and behavioral adaptations, including ways they are able to catch food, reproduce, and escape predators.

8. Closing discussion / reflection (5 – 15 min.)

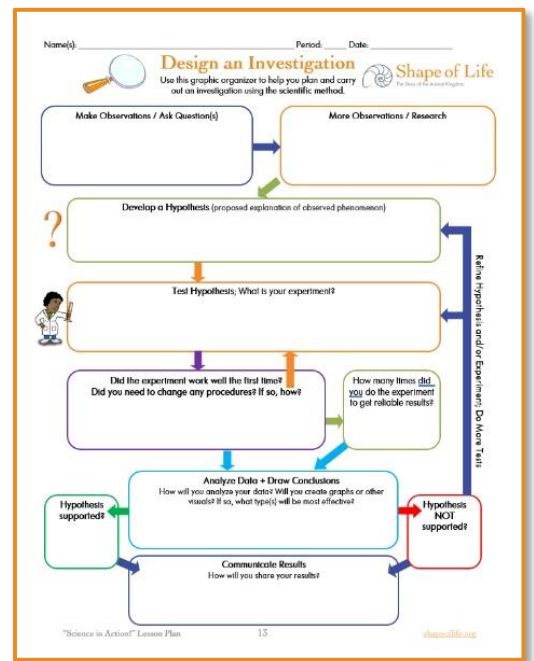
- Students can be asked to reflect on what they learned in the lesson, including about marine arthropod adaptations, orally and/or in writing. They can also be asked to reflect on what you, as the teacher, might do to improve the lesson next time.
- Ask how marine arthropod adaptations, such as jointed appendages and segmented bodies, help to explain the evolution of animals.

Extend / Enrich

- Conduct a field study into the marine arthropods found in your area—which could include the seafood section of the grocery store—so students can observe and compare real-life arthropods. (Will vary)
 - Visit the animals in their natural ecosystems, if possible, such as tidepools, but seeing organism at the grocery store or a seafood market—including live lobsters and crabs—is another great option.
 - Asian markets are a particularly good place to visit, because they often supply a wider variety of whole arthropods without their heads removed, etc.
 - You might purchase whole shrimp, crab, or another species to observe in the classroom and then cook and eat to give the students a chance to see what they taste like, too. If you decide to do this, send a permission slip home to parents/guardians to sign, especially to ensure there are no known seafood allergies. Families can also be invited to an event with food, possibly as part of a STEAM Night event that celebrates your arthropod unit and student projects.
- Have students design a useful new product inspired by the amazing adaptations of arthropods. (30 min. or more)
 - Watch the Shape of Life video “Arthropod Locomotion: Engineering” (7:15): shapeoflife.org/video/arthropod-locomotion-engineering.
 - Discuss the concept of biomimicry: using nature for inspiration to inspire human innovation. Drones and robots are already being developed based on their body plans, for instance. You might ask students to read an article, such as “Drones Become Even More Insect-like” in *Science* magazine, for additional information: science.sciencemag.org/content/368/6491/586.

- Consider stepping students through the design process with resources such as those included to support Lesson 7 of the *Investigating Crayfish + Freshwater Ecosystems* curriculum from The River Mile Network/National Park Service: therivermile.org/network-projects/the-river-mile-crayfish-study/complete-crayfish-curriculum.
- **Observe arthropods under magnification. (1 – 20 min.)**
 - If you have access to live or preserved marine arthropods, students can view them and/or their body structures under magnification via a microscope, hand lens, and/or macro lens to better see their unique adaptations.
 - You can also use a microscope or macro lens connected to a computer and/or data projector to show them to the whole class.
- **Dissect arthropods. (30 – 60 min.)**
You can prepare to lead students in a dissection—or they can lead themselves—with the support of videos and/or other resources listed below and at the end of the lesson, such as “Detailed Crayfish Dissection” (10:44): youtu.be/AOZdmUKoViY.
- **Students compare a marine arthropod species to another organism. (10–20 min.)**
 - Ask the students to compare a marine arthropod with another organism—either a modern one or an ancient ancestor. For example, a Venn diagram or another type of graphic organizer could be used. Then students could explain their graphic organizers in writing.
 - Oral presentations can be given to the class which explain the analytical comparisons.
- **Discuss current events related to one or more marine arthropod species. (5 – 20 min.)**
 - Find some local news highlighting issues related to arthropods, such as crustaceans impacted by ocean acidification or warming ocean. This will make the activities and discussions more relevant and personal to the students, as well as highlight important environmental issues.
 - Important news related to the impacts of overfishing on various marine arthropod species would also stimulate thinking and discussion.
- **Students can conduct in-depth research projects about a marine arthropod species, its life cycle, and/or one or more of its adaptations. (40 min. or more)**
Encourage students to use resources from Shape of Life and other authoritative sources, as well as connect with the school librarian(s). Suggest public libraries and librarians as invaluable in the research process, too.
- **Students can write fictional stories or poems that involve marine arthropods. (15 min. or more)**
Stories can include one or more arthropod species. For example, it might be an imaginative piece about a day in the life of a marine arthropod, or it could be set in a tidepool with crabs and other organisms attempting to cope with a warming ocean and ocean acidification.
- **Set up learning/exploration centers and offer students a choice of activities.**
Classroom centers can be set up with other activities related to arthropods and their adaptations, such as those listed above. This would provide more opportunity for student choice and differentiated learning experiences to maximize intrinsic motivation, engagement, and learning.

- Students can plan (and possibly also conduct) their own investigations into arthropod species. (30 min. or more)
 - Challenge students to think about how they might design their own investigation to prove how and/or why an observed phenomenon occurs related to an arthropod. Use prompts like:
 - “How might we design an investigation using a marine arthropod (living or already deceased)?”
 - “What materials might we need (and already have) to test interesting phenomena we observe?”
 - “How might we collect data?”
 - “How might we analyze the data and share it with others?”
 - Pass out copies of the “Design an Investigation” organizer found at the end of the “Science in Action!” lesson plan from Shape of Life: shapeoflife.org/lesson-plan/sol/science-action.
 - Have students form groups of 2 – 4 and use the organizer, their science notebooks, and/or a computer to help them develop an investigation plan. After groups start developing their ideas, ask the groups with especially interesting ones to share them with the class. This will help them refine their ideas and assist the other groups with developing their plans.
 - Decide as a class which investigation(s) the students want to conduct. Each group might want to conduct their own unique experiment, or the groups could break a larger investigation into smaller parts for each of the groups to investigate.
 - **Ideas for student projects** if they need help generating them:
 - How is climate change impacting the populations of lobsters? Students can collect data online from sources such as NOAA: climate.gov/news-features/climate-and/climate-lobsters.
 - How does water temperature impact survival rates of lobsters and/or crabs?
 - Groups could test the growth rate of marine arthropods under different conditions: varying amounts of food, water, light, salt, water pH, etc.
 - Are there more crayfish in freshwater bodies in urban areas or rural areas? Though crayfish live in freshwater, they are crustaceans like most marine arthropods, and closely related to lobsters.
 - Students could also create presentations and/or videos about their investigations and results.



“Design an Investigation” graphic organizer found at end of “Science in Action!” lesson plan: shapeoflife.org/lesson-plan/sol/science-action

Expand Knowledge + Skills

Arthropod Background + Nonfiction Readings

- “The Marine Arthropods: A Successful Design.” Shape of Life: shapeoflife.org/sites/default/files/global/MarineArthropods.pdf
- Featured Creatures from Shape of Life (students can choose one to read about and investigate further):
 - “Creature Feature: Krill and Whales”: shapeoflife.org/news/featured-creature/2019/07/03/creature-feature-krill-and-whales
 - “Dungeness Crab”: shapeoflife.org/news/featured-creature/2016/05/20/dungeness-crab
 - “Horseshoe Crab (*Limulus polyphemus*)”: shapeoflife.org/news/featured-creature/2017/05/19/horseshoe-crab-limulus-polyphemus
 - “Nauplii Larvae”: shapeoflife.org/news/featured-creature/2018/05/16/nauplii-larvae
 - “Thank Goodness We’ve Got Crabs” (sand crabs): shapeoflife.org/news/featured-creature/2015/02/25/thank-goodness-we%E2%80%99ve-got-crabs
- “Arthropods: A Success Story.” Understanding Evolution: Univ. of California, Berkeley: evolution.berkeley.edu/evolibrary/article/0_0_0/arthropods_intro_05
- “Phylum Arthropoda.” Exploring Our Fluid Earth: Teaching Science as Inquiry (TSI). Univ. of Hawai‘i: manoa.hawaii.edu/exploringourfluidearth/biological/invertebrates/phylum-arthropoda
- “Introduction to the Arthropoda...the REAL rulers of the Earth.” Univ. of California Museum of Paleontology: ucmp.berkeley.edu/arthropoda/arthropoda.html
- “Arthropods.” projects.ncsu.edu/project/bio402_315/arthropods/a01.html
- Krisfalusi-Gannon et al. (2018). “The Role of Horseshoe Crabs in the Biomedical Industry and Recent Trends Impacting Species Sustainability.” *Frontiers in Marine Science*: frontiersin.org/articles/10.3389/fmars.2018.00185/full
- “Trilobite.” Wikipedia (also references many other excellent sources): en.wikipedia.org/wiki/Trilobite

Related Lesson Plans / Activities

- “Phylum Arthropoda – Questions” (to accompany “Marine Arthropods: A Successful Design” video) Shape of Life: shapeoflife.org/sites/default/files/global/phylum-arthropoda-questions.pdf
- “Activity: Aquatic Invertebrate Behavior.” Exploring Our Fluid Earth: Teaching Science as Inquiry (TSI). University of Hawai‘i: manoa.hawaii.edu/exploringourfluidearth/biological/invertebrates/phylum-arthropoda/activity-aquatic-invertebrate-behavior
- “Invertebrate Critter Cards.” Shape of Life: shapeoflife.org/sites/default/files/lesson-plans/Invertebrate%20Critter%20Cards%20Activity_0.pdf
- “Question Set: Phylum Arthropoda.” Exploring Our Fluid Earth: Teaching Science as Inquiry (TSI). University of Hawai‘i: manoa.hawaii.edu/exploringourfluidearth/biological/invertebrates/phylum-arthropoda/question-set-phylum-arthropoda
- “World’s Most Awesome Invertebrate.” Shape of Life: shapeoflife.org/sites/default/files/SoL-Lesson-Awesome-Invertebrate_0.pdf

Related Videos

- Explore the other Shape of Life arthropod videos: shapeoflife.org/arthropod
- “Detailed Crayfish Dissection” (10:44). SDPB: youtu.be/AOZdmUKoViY
- “Learning about Arthropods.” Fun student project: youtu.be/Zr4jyhlCvw

Standards

- Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: nextgenscience.org/framework-k%E2%80%9312-science-education
- Examples of what NGSS looks like for California students can be found in the 2016 Science Framework for California Public Schools: cde.ca.gov/ci/sc/cf/documents/scifwchapter4.pdf
- Common Core State Standards and links to the complete documents: corestandards.org



Appreciation + Thanks

Thank you for using Shape of Life resources and helping to inspire the next generation of thinkers and scientists! We also greatly appreciate all of the scientists who have been collaborating with us to produce the videos and supporting resources. We welcome your questions or comments.

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Marine Arthropod Trivia

1. Put an "X" or checkmark in front of all the marine animals below that are classified as arthropods.

___ Corals

___ Oyster

___ Crabs,

___ Shrimp

___ Octopuses

___ Starfish

2. Marine Arthropods are:

___ Carnivores

___ Omnivores

___ Herbivores

___ All of these

3. Mark all the things below that marine arthropods eat.

___ Algae

___ Plants

___ Fish

___ Bacteria

___ Zooplankton

4. All arthropods have straight **appendages** (like legs and antennae).

___ True

___ False

5. All arthropods have an **exoskeleton** that provides support and protects their soft internal organs.

___ True

___ False

6. Some juvenile marine arthropods don't look like the adults

___ True

___ False

7. Molting is the process in which an arthropod sheds its exoskeleton to make room for a new, larger one.

___ True

___ False

Arthropod Glossary

appendage	parts attached to the main body like claws and antennae
antenna	one of two long sensory organs at front of arthropods such as insects and crustaceans (antennae : two or more)
arachnid	arthropod in class Arachnida ; predatory or parasitic animals that have 8 legs, such as spiders, scorpions, and ticks
arthropod	animal in phylum Arthropoda that includes animals with exoskeletons and jointed appendages; includes over 85% of known animal species
biomimicry	design and creation of products, materials, and/or systems inspired by biological organisms
chitin	a substance that provides a tough, protective covering; similar to keratin, the substance that human hair and nails are made from
crustacean	an arthropod in subphylum Crustacea that includes lobsters, crayfish, crabs, and shrimp
gills	internal feathery organs in marine/aquatic arthropods (as well as fish) used to extract oxygen from the water
exoskeleton	hard external covering of various animals, including arthropods, that provides attachment for muscles and protects the animal from drying out and injury
evolution	process by which organisms change over time through natural selection
insect	arthropod in class Insecta ; insects comprise 75% of known animal species
hydrothermal vent	hot springs on ocean floor—especially along the mid-ocean ridges—that supply nutrients to ecosystems that are very different from those found elsewhere on Earth Different species of crabs and lobsters have been found living in hydrothermal vent communities.
krill	small marine crustacean that resembles shrimp; important part of some whale, seal, and fish species' diets
larva	free-living, immature stage in the life cycle of many animals (such as arthropods); often very different in appearance from adult stage and usually incapable of reproduction
marine	found in or related to the sea
molting	in arthropods, the periodic process by which the exoskeleton is discarded and replaced by a new, larger one that allows the animal to grow
myriadpod	arthropod in subphylum Myriadpoda that includes centipedes and millipedes
natural selection	process in which organisms better adapted to their environment survive to produce more offspring
segmented	the body is made up of a basic body compartment and the body gets bigger by adding more compartments. Like a classic train with its engine and caboose, segmented animals have repeating segments between specialized front and back compartments
terrestrial	found on or related to land
trilobite	arthropod from extinct group found in fossil record from about 521 million years ago until about 252 million years ago; diverse species were scavengers, predators, and filter feeders

Presentation Rubric

Title: _____

Presentation Component	Maximum Points Possible	Self-Score (fill out before presentation)	Teacher Score
Part 1: Content			
Subject and purpose of presentation clearly introduced	10		
Key concepts identified and clearly explained in well-organized way	10		
Ideas supported by examples, data, graphs, etc.; All information accurate and obtained from reliable sources	10		
Conclusion summarizes key points in persuasive way; Questions answered thoroughly and accurately	10		
Part 2: Delivery / Audience Engagement			
Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft)	10		
Speed, volume, and voice inflection are varied to engage audience and emphasize key points	10		
Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen	10		
Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker	10		
Part 3: Visuals			
Visuals help to clearly explain concepts	10		
Part 4: Writing Conventions			
Grammatical and spelling conventions followed	10		
TOTALS:	100		

Comments: