Ocean Origins of Life

Grade Level

6–8 or higher

Timeframe

45 minutes or more

Materials

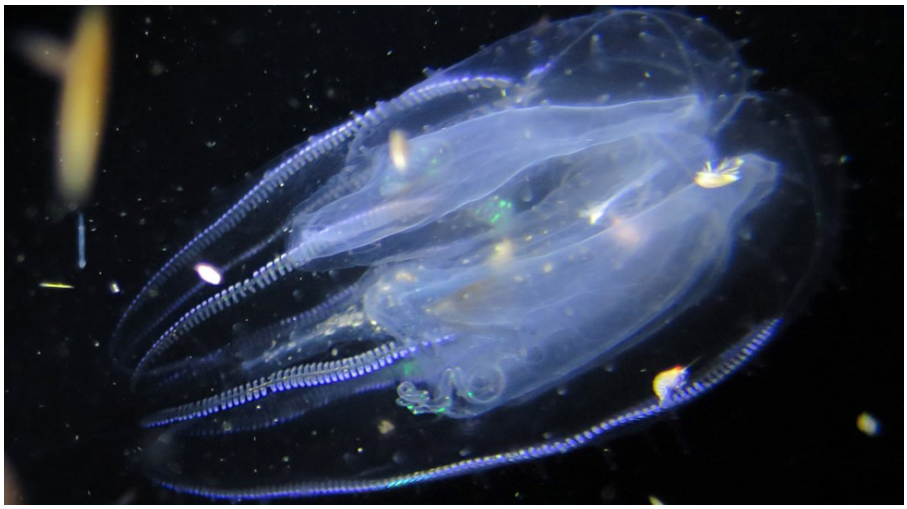
- Computer, projector and screen
- Visual materials (all available to download)
- Text documents (all available to download)

Key Words

Adaptation, body plan, evolution, fossil, origins of life

Standards

NGSS: MS-LS4-1. MS-LS4-2.
CCSS: W.6.10. SL.6.4.
Ocean Literacy Principles: 4, 5.
Climate Literacy Principles: 3.
Details at end of lesson



A bioluminescent comb jelly (Ctenophore) at Hawaiian Islands Humpback Whale National Marine Sanctuary. What evolutionary clues do they contain? Photo: Olivia Williamson/NOAA

Activity Summary

Students explore the evolution of marine organisms. They use cards showing images of extinct organisms and attempt to match brief descriptions with the correct organisms. Then they try to order these from simplest to most complex anatomical structures and body systems. They hypothesize which organisms (or group to which the organism belongs) evolved first. Then they match living species with their extinct relatives, noting similar traits. Students research where in national marine sanctuaries the living species are found and create a sanctuary poster featuring the organism. The teacher facilitates discussion about the importance of the ocean in the evolution of life.

Learning Objectives

Students will:

- Analyze and look for patterns in the level of complexity of anatomical structures in organisms and hypothesize about the chronological order of organism appearance in the fossil record
- Construct an explanation for the anatomical similarities and differences between modern and fossil organisms to infer evolutionary relationships
- Understand life originated in the ocean and organisms on Earth today are related by descent from common ancestors that evolved in the ocean

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National Geographic Society

&

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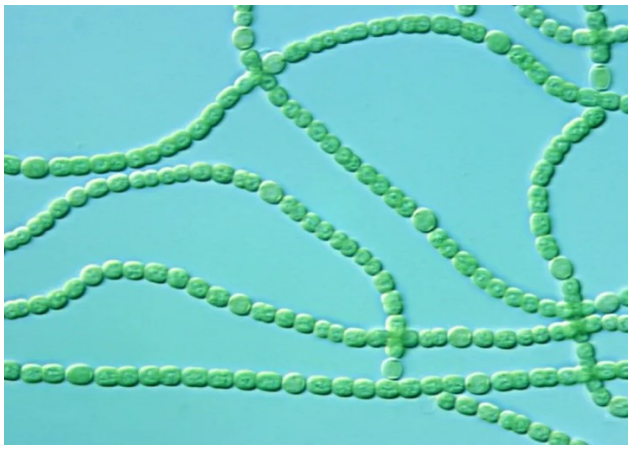
Background Information

Life evolved in the ocean about 3.8 billion years ago. Life on Earth for most of this time was dominated by single-celled microbes lacking a nucleus (probably prokaryotic organisms). Cyanobacteria (blue-green algae), the ancestors of all plants and algae, are among the oldest fossils known on Earth. These three-billion-year-old prokaryotes are found in layers of ancient ocean sediments called stromatolites.



Magnified cyanobacterium (blue-green algae)
Photo: Argonne National Lab

Earth's Early Atmosphere

Earth's early atmosphere consisted of carbon dioxide, methane and water vapor. There was very little oxygen. Cyanobacteria were mostly responsible for the first free oxygen in Earth's atmosphere, as a by-product of photosynthesis. Oxygen began to accumulate around 2.4 billion years ago. The oxygen released by cyanobacteria gradually accumulated throughout the ocean and oxygenated the water. Slowly, the accumulated oxygen started escaping into the atmosphere, allowing for the possibility of oxygen-breathing organisms.

The First Multicellular Organisms

Eukaryotes, organisms with a true nucleus and complex internal cell structures, evolved by around two billion years ago. Eukaryotic organisms require oxygen, so life could not become more complex until the oceans and atmosphere contained enough oxygen to support their evolution. These organisms were the first to become multicellular. Around 600–700 million years ago the first complex multicellular life forms evolved, and around 542 million years ago the first complex animals emerged.

Before the Cambrian Explosion (542 million years ago) of animal life in the ocean, there is evidence that three groups of primitive animals existed: the ancestors of jelly-like, worm-like and sponge-like organisms. Scientists have debated whether sponges or another group of organisms were the first animals. Recent DNA evidence now suggests an organism related to modern comb jellies (shown above) could have been the first (Schultz, et al. 2023). Recent evidence indicates that sponges may have come into existence as long as 890 million years ago (Wei-Hass 2021), but scientists still debate this.

The Cambrian Explosion

The evolution of animals with bilateral symmetry marks the beginning of the Cambrian Explosion, which lasted approximately 20 million years. This is when the vast majority of animal groups still alive today first appeared in the fossil record. Out of 35 phyla that emerged during the Cambrian Explosion, most animals alive today are members of only eight: sponges, cnidarians, flatworms, annelids, arthropods, molluscs, echinoderms and chordates.

One of the most important fossil deposits dating from the Cambrian Explosion is the Burgess Shale, located in the Rocky Mountains of British Columbia, Canada. It contains fossils of almost 200 species, including fossils of marine algae and rarer soft-bodied organisms. The Burgess Shale reveals what life was like in the ocean for millions of years. The fact that the Burgess Shale is hundreds of miles from the Pacific Ocean basin reveals that the ocean had a much different footprint than it does today.

Evidence in National Marine Sanctuaries

National marine sanctuaries are a network of underwater areas in the ocean and Great Lakes that protect America's most iconic natural and cultural marine resources. Millions of years ago the ocean extended much further inland; thus, fossils of marine organisms are often found far from coasts. However, some sanctuaries and areas near sanctuaries harbor fossil evidence. More than 600 species are fossilized in the sediments of Calvert Cliffs in Maryland, near the Mallows Bay-Potomac River National Marine Sanctuary. Near the Calvert Cliffs a young girl discovered a 5-inch tooth from *Otodus megalodon*, which lived approximately 15 million years ago! In addition, fossilized scallops and whale bone fragments have been found at Gray's Reef National Marine Sanctuary.

Importantly, our national marine sanctuaries harbor the dynamic and diverse organisms that descended from ancient ocean-dwellers. In fact, most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land. Studying the DNA of existing species provides clues about the relationships between organisms and the very beginnings of life on Earth.

A megalodon tooth with great white shark teeth
Photo: Brocken Inaglory CC BY-SA 3.0

Learn more:

Callier, V. (2023). "The Closest Living Relative of the First Animal Has Finally Been Found." *Scientific American:* https://www.scientificamerican.com/article/the-closest-living-relative-of-the-first-animal-has-finally-been-found

"Cambrian Explosion." National Geographic Society: https://www.nationalgeographic.com/science/article/cambrian

"The Great Oxidation Event: How Cyanobacteria Changed Life." American Society for Microbiology: https://asm.org/Articles/2022/February/The-Great-Oxidation-Event-How-Cyanobacteria-Change

"Museum of Natural History Early Life on Earth – Animal Origins." Smithsonian: https://naturalhistory.si.edu/education/teaching-resources/life-science/early-life-earth-animal-origins

Schultz, D.K. et al. (2023). Ancient gene linkages support ctenophores as sister to other animals. *Nature:* https://www.nature.com/articles/s41586-023-05936-6

Wei-Hass, M. (2021). "890-million-year-old sponge fossil may be the earliest animal yet found." *National Geographic*: https://www.nationalgeographic.com/science/article/890-million-year-old-sponge-fossil-may-be-the-earliest-animal-known

Vocabulary	
Adaptation	A trait an organism has that helps it to survive in its environment; maintained through natural selection
Anatomical structure	Body part
Bilateral symmetry	Left side of the body is a mirror image of right side of body
Body plan	Basic form and structure common to many members of a phylum of animals; examples are radial symmetry (cnidarians, echinoderms) and bilateral symmetry (most animals, such as arthropods and vertebrates)
Evolution	The change in inherited characteristics of organisms over successive generations
Fossil	The preserved remains or signs of animals and plants that lived more than 10,000 years ago
Natural selection	A key mechanism of evolution: Some individuals survive and reproduce more than other individuals due to differences in traits.
Stromatolite	Fossilized layers of cyanobacteria

Preparation

- Print copies of the "Ocean Origins of Life Organism Cards," one set for groups of 2–3 students. Cut up the cards in advance and prepare to distribute them in two separate sets to each group:
    - One set of the ancient organisms and the descriptions of them (with the descriptions cut and separated from the images)
    - One set of the modern organisms and descriptions (with the descriptions cut and separated from the images)
    - Note: The heading text color and organism name on the ancient organism cards is a darker blue to help you keep track of which card belongs with which set.
- Prepare to share the "Ocean Origins of Life" PowerPoint presentation.
- Print copies of the "Sanctuary Survivors Poster Presentations" rubric found at the end of the lesson, one per student.

Procedure

Engage

- Show students one of the videos from Parks Canada's Virtual Sea Odyssey: https://burgess-shale.rom.on.ca/virtual-sea-odyssey. "Descent" is a good option: https://burgess-shale.rom.on.ca/virtual-sea-odyssey. We recommend clicking the full-screen view button in the lower-right before playing it.
    - Ask students: Do you recognize any of these organisms? What are they or what other organisms do they resemble? Ask them to turn to a neighbor to share their ideas, recording them in science notebooks.

- After a minute, ask the students to share their ideas with the class. Discuss how the video provides a glimpse into what early life in the oceans was like hundreds of millions of years ago. It shows animations of extinct organisms based on fossil evidence and observations of living organisms in the ocean.
- Ask:
  - What do you think was the first animal? Where do you think it lived?
  - What are fossils and why/how are they important for science?
  - Give students time to respond verbally or record ideas in science notebooks. You will clarify ideas later in the lesson.

Explore

- Ask students to form groups of 2–3. Pass out the extinct organism cards and descriptions of those organisms. Make sure the cards are shuffled so the descriptions do not pair with the matching images. Do not pass out the modern organism cards with their matching descriptions yet.
  - Ask students to try to pair the descriptions of the ancient organisms with the correct images.
  - Then ask them to decide which organism came first in the evolutionary tree of life. They should put the cards in chronological order.
    - Ask students to justify their decisions based on their observations of organism anatomical structures and body plan.
    - To help them think through this task, ask students to think about which organisms have simple body plans and structures versus those that have more complex body systems and structures.
    - Ask students to make notes in science notebooks.
  - Ask students to conduct research to check their ideas. They can use the "Ocean Through Time" page from the Smithsonian National Museum of Natural History at https://ocean.si.edu/through-time/ocean-through-time and/or other credible sources that explain the evolutionary timeline.
  - Ask students to check their card ordering with the information learned from sources. They should revise the order of their cards, as needed.
- Pass out the cards of living relative organisms found in national marine sanctuaries. Ask students to first match the image cards with their descriptions. Then they should match living organisms with their extinct relatives.
  - They should justify why they matched extinct and living organisms based on anatomical similarities. They can make notes in science notebooks.
- Ask students what adaptations help those organisms survive in a marine environment. Students can describe organisms' adaptations in science notebooks.

Explain

- Ask the groups to share their ideas about the evolutionary chronology of life. Share the questions and visuals from the "Ocean Origins of Life" PowerPoint to facilitate discussion. Be sure to emphasize that the evolutionary tree is not just one branch; multiple branches of organisms evolved. Some branches went extinct (like trilobites) while others continued, with living organisms representing that branch today.
- In a full class discussion, ask students what all of these organisms have in common. (They are all ocean-dwellers.)
    - Ask students: Where did life begin? What evidence do we have about where life began?
    - What can organisms that are alive today tell us about the past? Where can these living organisms be found?
- Explain the "Sanctuary Survivors" poster project described in the presentation:
    - Tell students that all of the living organisms on the cards are found in national marine sanctuaries. Ask students if they know what the sanctuaries are and give a brief description if they are unfamiliar.
    - Tell students that the sanctuaries need their help to educate the public about the organisms found there. Their assignment is to create a poster for a specific sanctuary where the organism is found.
        - Ask students to choose one of the living organisms on the cards and search the sanctuaries website (https://sanctuaries.noaa.gov) to find out where they are located. They could also choose a different organism found at a sanctuary that is related to one of the ancient organisms.
        - The poster should feature and include information about the organism and an extinct evolutionary relative.
        - They should explain the living organism's key traits, including:
            - Habitat(s) and ways it survives
            - What it eats and/or what eats it
        - The poster can also include information about similarities and differences between the living and extinct organisms, as well as evidence that each modern organism is related to the matching ancient organism.
        - Pass out copies of the "Sanctuary Survivors Poster Presentations" rubric found at the end of the lesson, one for each student. Explain that students should complete the "Your Score" column and turn it in to you when they are ready to present about their posters to the class.
        - Show students the sanctuary posters in the PowerPoint and here to inspire them: https://sanctuaries.noaa.gov/posters

Enrich/Extend

- Share Hawaiian mo'olelo (stories) of the origins of life. Kumulipo, Hawai'i's renowned genealogical creation chant, describes Hawaiian cosmology from the beginning of time. Part of the story is told during the "NOAA Live! 108 – Born is the Coral Polyp, A Creation Story from Hawai'i" webinar, starting at 4:39: https://youtu.be/vNwPGPOvkc8?si=xZG-o4O4caQWIrS5&t=279
    - You can make your own coral polyp art to help students remember and tell the story to others: https://seagrant.whoi.edu/wp-content/uploads/2021/12/Make-a-coral-polyp-final.pdf
    - Learn more in "Mai Ka Pō Mai," a historic guidance document, on page 8: https://www.papahanaumokuakea.gov/new-news/2021/06/21/maikapomai .
    - Hear a story in the Hawaiian language (with English subtitles) that begins with the Kumulipo and teaches about how the Hawaiian Monk Seal is an important part of marine ecosystems in Hawaii: https://videos.fisheries.noaa.gov/detail/videos/protected-species_/video/6333145655112/episode-1:-kai-p%C4%81pa%CA%BBu-shallow-waters
- Ask students to compare and contrast the anatomical features/adaptations of an ancient and modern organism. Or they could compare two modern organisms found in sanctuaries using a Venn diagram. One option to engage students before doing this activity would be to have them explore the Flower Garden Banks virtual reality video of a barrel sponge: https://sanctuaries.noaa.gov/vr/flower-garden-banks/barrel-sponge. Then you could ask students to research barrel sponges and compare them to another organism. Another option is to ask students to read about the discovery of a megalodon tooth by a Maryland girl and compare the huge ancient sharks to modern white sharks or another organism: https://www.npr.org/2023/01/12/1148441701/ancient-shark-tooth-megalodon-fossil-maryland-christmas.
- Students can create their own fossils using clay, Play-doh or plaster of Paris. An activity handout can be found at the end of NOAA's lesson "The Methane Circus": https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_circus.pdf
- Invite students to play the "Evolve or Perish" Board Game from the Smithsonian National Museum of Natural History: https://naturalhistory.si.edu/education/teaching-resources/paleontology/evolve-or-perish-board-game.
    - Students can explore other interesting paleontology resources at https://www.amnh.org/explore/ology/paleontology.
    - The "Layers of Time Fossil Game" and short explanatory video will help them understand how fossils are created and used by paleontologists to construct a chronology of life on Earth: https://www.amnh.org/explore/ology/paleontology/layers-of-time2

- Ask students to research the causes and impacts of the Permian extinction, the largest extinction event in Earth's history. The "Oceans in Time" page from Smithsonian is one good resource: https://ocean.si.edu/through-time/ocean-through-time.
    - Ask students to compare the Permian extinction's causes to factors impacting our own rapidly changing climate. Ask: What types of pollution/gases are changing our atmosphere and ocean today?
    - What steps can we take to reverse these harmful trends to protect our atmosphere and ocean, as well as land areas and our human communities that depend on them?

Evaluate

- Review students' science notebooks for their notes about the organism card ordering activity.
- Review students' posters and presentations. Provide feedback with the rubrics.
- Ask students to construct a chronology of the evolution of life on Earth. They can record ideas in science notebooks or on separate paper. Students might also choose to add illustrations with labels to their written accounts. Reference sources such as those listed above and below could be used to help with the process.

Education Standards	
Next Generation Science Standards	Biological Evolution: Unity and Diversity • 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 under the assumption that natural laws operate today as in the past. Science and Engineering Practices: • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information Crosscutting Concepts: • Cause and Effect • Structure and Function • Stability and Change
Common Core State Standards	Writing: W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. Speaking and Listening: SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.
Ocean Literacy Principles	4. The ocean makes Earth habitable. (b) 5. The ocean supports a great diversity of life and ecosystems. (a)
Climate Literacy Principles	3. Life on Earth depends on, is shaped by, and affects climate. (a, c) (If the last Enrich/Extend activity is completed.)

Additional Resources

"Ages Ago" lesson plan. NOAA: https://gml.noaa.gov/education/lesson_plans/Ages%20Ago.pdf

"Fossils." National Park Service: https://www.nps.gov/grca/learn/nature/fossils.htm

"Native Hawaiian Culture." Hawaiian Islands Humpback Whale National Marine Sanctuary: https://hawaiihumpbackwhale.noaa.gov/heritage/native-culture.html

"Ocean Through Time." Smithsonian Institution: https://ocean.si.edu/through-time/ocean-through-time

"What are Comb Jellies and Why is Their Poop Important?" National Geographic video (1:48): https://youtu.be/JfiFKievLVs

"What's a Ctenophore?" NOAA National Marine Sanctuaries video (0:46): https://sanctuaries.noaa.gov/earthisblue/wk187-what-is-a-ctenophore.html

For More Information

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Name: _____Per.: _____ Date: _____

Sanctuary Survivors Poster Presentations

Title: _____

Part 1: Content	**Maximum Points Possible**	**Your Score** (fill out before presentation)	**Teacher Score**
Name and location of sanctuary clearly introduced	10		
Living organism's key traits explained, including: • Habitat(s) and ways it survives • What it eats and/or what eats it	10		
Ancient organism ancestor clearly explained, as well as evidence that the modern organism is related to the ancient one	10		
All information accurate and obtained from reliable sources	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: