Kelp Forest Coevolution: Lesson 4 Teacher Guide & Student Materials
Elaborate

Objective(s):

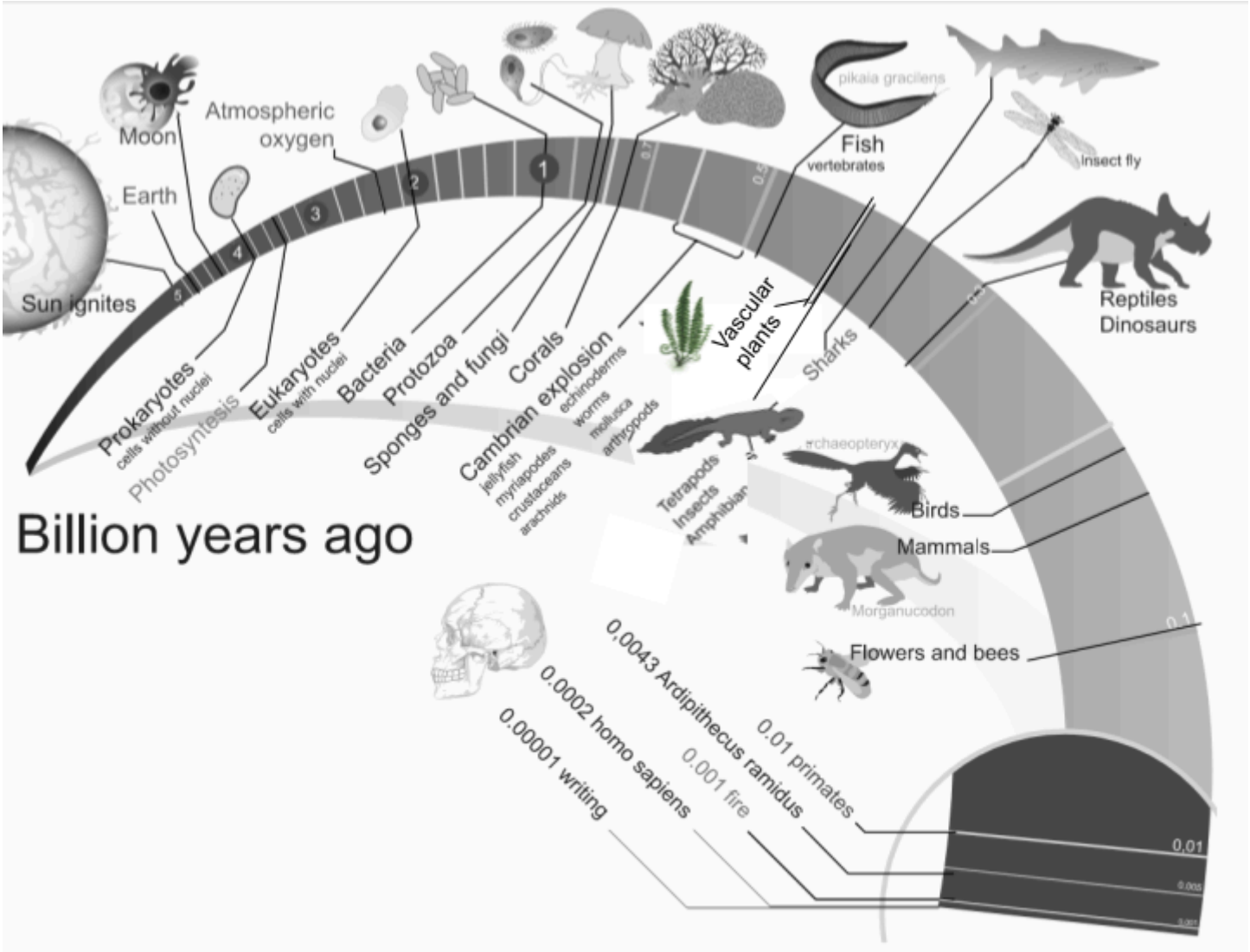
- Students can explain how the evolution of kelp was driven by global climate factors, and also itself drove local ecosystem changes

Teacher Guide:

[5 minutes] Bellringer: Which do you think came first, pandas or bamboo? Why?
Students answer Bellringer question on the handout (first row) or in a notebook.
Teacher can ask for volunteers or cold-call to share answers, and may write some ideas on board.

Secondary bellringer if activity done over 2 days is pasted below:

Earth Evolutionary Timeline *Source: Wikimedia Commons*



1. Look at the timeline. What do the numbers mean?
2. Estimate how long ago Earth formed:
3. Find "Photosynthesis." How long ago did this important process evolve?
4. What type of organisms do you know that do photosynthesis? Bonus: From prior knowledge, what happens during photosynthesis?

5. Find the earliest animal you can on this timeline. What is it? So did animals evolve before or after the photosynthetic organisms?

[60* minutes] Kelp Forest Evolution Activity

Students look up key vocabulary words (could jigsaw or do individually, using chromebooks or pre-made "vocab stations" around the room), THEN do a group-read of an excerpt from a scientific article. After reading, students answer questions.
Teacher prepares the vocabulary activity, could read the article excerpt aloud, and supports students to answer the questions after reading.

* Add another 30 minutes if you have students do the optional #10 "Extend" question. This could be done as independent or partner research, or as a class done using a short video on the kelp forest ecosystem (even re-watching the video from Lesson #1) to find examples of other co-evolved species

Kelp Forest Evolution

Name: _____

Date: _____ Period: _____

Article Pre-Work: Vocabulary

Define each of the following terms, which will be used in the article.

marine	
terrestrial	
analog	
temperate	
harvestable	
diversification	
phylogenetic	
sequence divergence	
limpet	
mid-latitude	
Molecular clock	

Article Comprehension Questions

Read the "Comprehensive Kelp Phylogeny" excerpt, then answer the questions:

1. Restate in your own words what "marine analog to temperate forests" means:

2. What THREE purposes or benefits do the authors say kelp forests have?

3. The authors say that for much of history, how was the Pacific Ocean different than it is today?

4. The authors say that kelp probably evolved recently, and give 2 pieces of evidence for it. Explain in your own words how each piece supports their point:
    a. The molecular phylogenetic evidence

    b. The stipe-grazing limpets evidence

5. When do the authors say kelp actually did evolve?

Examine the diagram to the right, which shows ocean temperature over the last 65 million years.

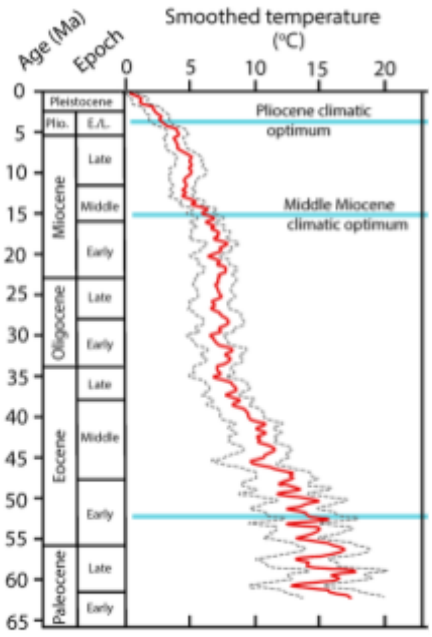
6. Estimate the ocean temperature around 60 million years ago:

7. Estimate the ocean temperature around 30 million years ago:

8. So how has the average ocean temperature been changing in the last 60 million years?

9. How could this graph be used to support the authors' claims that "kelps evolved and diversified during periods of global cooling, perhaps taking advantage of newly available mid-latitude habitats"? *(Hint: Use answers from #5 and #8)*

10. Extend: Limpets are an example of an animal that evolved after the kelp forest, and depends on it. Research THREE other animals that depend on the kelp forest, and summarize how, on a separate piece of paper.



Johnson, M. E. (2021). Geological oceanography of the Pliocene warm period: a review with predictions on the future of global warming. *Journal of Marine Science and Engineering*, *9*(11), 1210.

The following is an adaptation from the article:

Molecular Phylogenetics and Evolution

Volume 136, July 2019, Pages 138-150

A comprehensive kelp phylogeny sheds light on the evolution of an ecosystem

Samuel Starko [a b c], Marybel Soto Gomez [a], Hayley Darby [a], Kyle W. Demes [d], Hiroshi Kawai [e], Norishige Yotsukura [f], Sandra C. Lindstrom [a], Patrick J. Keeling [a d], Sean W. Graham [a], Patrick T. Martone [a b c]

Introduction

Brown algae…are the most productive and one of the most ecologically significant [groups] of macroalgae in the world *(Leigh et al., 1987, Steneck et al., 2002, Teagle et al., 2017)*. The biomass-rich communities formed by kelps provide a **marine analog** to **terrestrial** forests, reaching tens of metres high and producing dynamic and essential habitats along **temperate** coastlines worldwide *(Bolton, 2010, Graham, 2004, Kawai et al., 2016, Steneck et al., 2002)*. Kelps increase the productivity of nearshore ecosystems both as a source of food *(Duggins et al., 1989)* and by providing habitat for a variety of other organisms *(Miller et al., 2018, Teagle et al., 2017)*. Kelps have also long provided ecosystem services to humans both directly as a **harvestable** resource (e.g., for food and valuable extracts; *Bartsch et al., 2008*), and indirectly by increasing ecosystem productivity *(Kremen, 2005, Smale et al., 2013, Steneck et al., 2002)*. …

… Kelps are found primarily in temperate regions *(Assis et al., 2017, Bolton, 2010, Graham et al., 2007)*, and their global range is currently decreasing as climate change and extreme marine heat waves drive range contractions around the world (*Filbee-Dexter and Wernberg, 2018, Krumhansl et al., 2016, Wernberg et al., 2016, Wernberg et al., 2012*). Yet, for much of the earth's history, the oceans, including the Pacific Ocean, were warmer than they are today. … Thus, it has been proposed that the [**diversification**] of complex kelps, currently distributed globally, occurred only recently (*Estes and Steinberg, 1988*). This is supported by molecular **phylogenetic** evidence showing relatively little **sequence divergence** among divergent kelp species (*Saunders and Druehl, 1992*). Moreover, kelp-associated species, such as stipe-grazing **limpets**, which have specific shell morphologies allowing them to graze cylindrical kelp stipes, do not appear in the fossil record until [5 million years ago], further suggesting that kelp-dominated ecosystems are not ancient (*Estes and Steinberg, 1988*). … It is therefore generally thought that kelps evolved and diversified during periods of global cooling, perhaps taking advantage of newly available **mid-latitude** habitats (*Bolton, 2010, Vermeij et al., 2018*). This hypothesis is consistent with early **molecular clock** analyses that suggested that most kelp diversity evolved within the past 30 million years …

Kelp stipe with a limpet on it