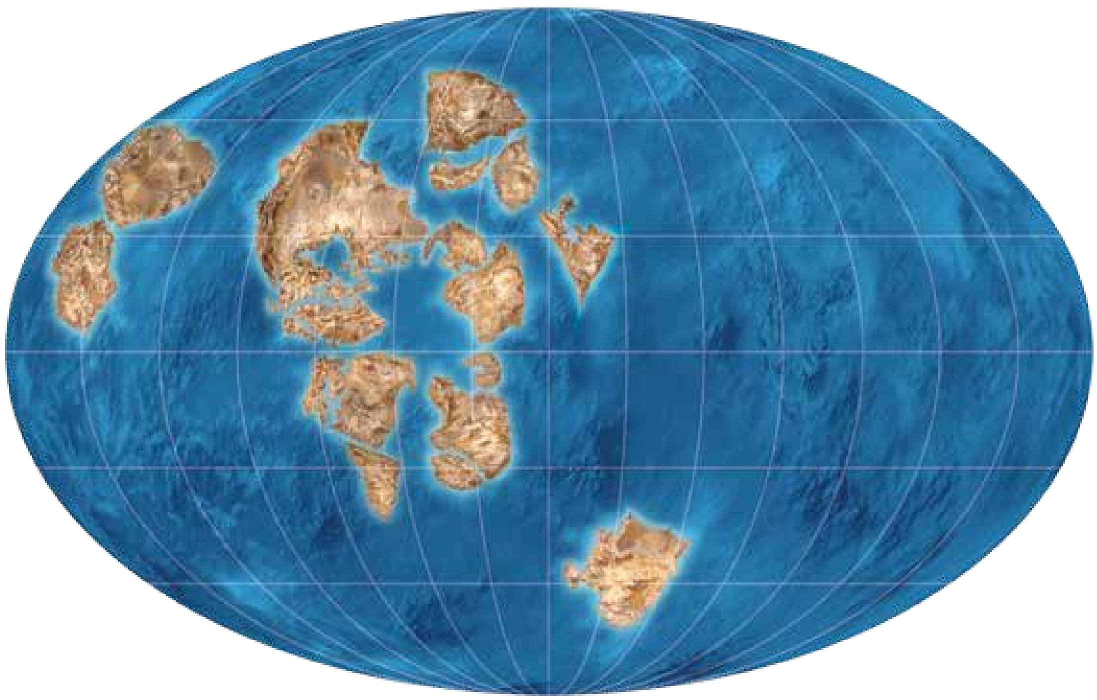
Science News

IN HIGH SCHOOLS | EDUCATOR GUIDE



EARTH'S (Not So Boring) BORING BILLION

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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About the article

The *Science News* article "Earth's (Not So Boring) Boring Billion" examines a period in Earth's history that was once believed to be uncharacteristically uneventful. Recent research shows that there are enduring mysteries associated with this time period and that, despite low oxygen levels, it likely set the stage for the emergence of animals. The more scientists understand this unique moment in history, the more they feel they can learn about the conditions required for life to thrive here and, perhaps, on distant planets.

"Earth's (Not So Boring) Boring Billion" can be used across a wide range of curricula, with a focus on biology and Earth's history. The activities, questions and discussions in this educator guide can be used to support the following education standards:

Next Generation Science	Common Core
Natural Selection and Evolution: HS-LS4-2, HS-LS4-5	ELA Standards: Reading Informational Text (RI): 1, 3, 4,
History of Earth: HS-ESS1-5	ELA Standards: Writing (W): 1, 2, 4, 6, 8, 9
Earth's Systems: HS-ESS2-2, HS-ESS2-3, HS-ESS2-7	ELA Standards: Speaking and Listening (SL): 1, 4
	ELA Standards: Language (L): 3, 4, 5, 6
	ELA Standards: Reading for Literacy in History/Social Studies (RH): 3
	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 4, 6, 8
	ELA Standards: Writing Literacy in Historical/Social Studies and Science and Technical Subjects (WHST): 1, 2, 8, 9

Prior to reading

Guide student reading by pointing out connections between this article and what students are learning in class. Here, find some ideas for standard-aligned paths to follow while reading:

- Ask students what they already know about the geological history of Earth and how Earth's geology changes over time. They may know that Earth is 4.6 billion years old and that the Earth's outer layer is broken up into plates that move. Ask students how the shape of the continents and seafloor structures provide clues to past plate motions. If students are unfamiliar with this idea, you may want them to explore the theory of continental drift. One fun way is through the song "Continental Drift" by The Amoeba People.
- How did changes to Earth's environment create opportunities for organisms to develop and flourish? Conversely, how did organisms change the environment? Students may already know some key ideas related to ecological succession that they can use for brainstorming. They may also realize that dramatic events like volcanic eruptions and asteroid impacts eliminated life or created opportunities for new life. As students read, they may also consider how photosynthetic organisms slowly affected the chemistry of the atmosphere, developing the conditions that were perfectly suited for of the diversification of life.
- If your students haven't taken biology yet, some of the concepts in the article may be unfamiliar (eukaryotes, decay, oxidation, atom, atomic mass, isotope). Provide your students with a list of words and concepts from the article and ask them to explore the words and definitions using Blackline Master #1.
- Good writers use figures of speech to make their writing clear and interesting. Discuss examples with your students before reading (alliteration, pun, paradox). Ask them to see how many examples they can find in the article as they read. They can record the examples, and even come up with their own, using Blackline Master #2.

After reading: Comprehend

You can adapt and print these questions (Blackline Master #3) to check for comprehension and analysis before or after discussion:

1. **What is the main topic of the article?**
   (Scientists are examining a period of a billion years that was once thought to be uneventful for clues about the emergence of animals.)
2. **Why was the interval between 1.8 and 0.8 billion years ago considered the "dullest time in Earth's history"?**
   (The climate had stabilized, levels of oxygen remained low, early eukaryotes were present but animal life had yet to flourish.)

3. **How did the "boring billion" end?**
(Oxygen levels rose, evidence of early animals appeared.)

4. **Name a reason from the article to explain why scientists study Earth's history?**
(To better understand how life and the environment interact over time, to study the characteristics that could support or hinder the emergence of life on other worlds.)

5. **Why was the study of the breadcrumb sponge important?**
(Testing sponges for the amount of oxygen they actually need to survive helps scientists understand how animals could survive in low-oxygen conditions before our current atmosphere developed.)

After reading: Analyze

1. **What is the difference between eukaryotes and the life that evolved before them, called prokaryotes?**
(Depending on students' backgrounds, answers will vary. Prokaryotes — bacteria and archaea — do not contain membrane-bound organelles, and the cells reproduce through binary fission, a process in which daughter cells are genetically identical to the parent cell. Eukaryotes can be single- or multicelled and they use mitosis and meiosis to reproduce. Plants, animals and fungi are examples of eukaryotes. For a fuller description of mitosis and meiosis, see this page from the University of Manitoba.)

2. **What is the significance of chromium-53 and why is it different from other forms of chromium?** *(Because there is no direct record of the chemistry of ancient air or seawater, scientists used an indirect method to try to predict past oxygen levels. They looked for a substance that changes in the presence of oxygen. Bacteria in soil oxidize manganese for energy. The oxidized manganese in turn oxidizes chromium in the soil. Chromium-53 is an isotope of chromium. Students might remember learning about isotopes in chemistry.)*

3. **The article quotes one scientist who has changed his thinking about the strength of the role of plate tectonics in the development of Earth's atmosphere. What types of events have changed the chemistry of Earth's atmosphere in the past?** *(Answers will vary but might include: the formation of new rocks, breakdown of organic matter, photosynthesis, cellular respiration, volcanic activity and so on.)*

Discuss and Assess

After students read the article independently, return as a group to the concepts outlined prior to reading. Invite students to share their answers and observations from the article and lead a class discussion that further underscores your current curriculum. The discussion can serve as an informal assessment. Ideas for further reading discussion or writing prompts include:

- Discuss the factors that influence what a scientist decides to study. Explore ideas from the article to support your point of view. *(Linda Kah raises the issues of funding and tapping into the public's imagination — what's cool. The structure of academia — with professors mentoring students — often means that areas that are already being studied get more attention that brand-new areas. At the core, only ideas that can be scientifically tested, such as the ability of breadcrumb sponges to survive under different levels of oxygen, can be studied.)*
- The article discusses evidence of animals appearing before the end of the "boring billion" timeframe. Ask students to think about what environmental events might have opened a window for these animals to evolve. How were they different from the life that came before? How might they have been different from the animals we find on Earth today? Might some of them still be around today? Encourage students to argue based on evidence. Ask them what kind of experiments they might devise to better understand these early animals. *(Students can postulate a number of answers to the first question, creating persuasive arguments based on information in the article. Some possible arguments include: Microbes created enough oxygen in limited locations — an oxygen oasis — that early animals were able to utilize it for their survival; early animals were adapted to hydrogen sulfide, like the bacteria and archaea living by deep-sea vents today. Allow students to form their own hypotheses about the nature of these animals and then encourage students to consider how they might test these hypotheses.)*
- This article examines how Earth's atmosphere changed over time and the impact of these changes on the development of life. Discuss why a changing atmosphere would be so interesting to the public now, given the worldwide attention on climate change. Ask students what activities are changing the atmosphere today and encourage them to think about whether they have had a part in changing the composition of Earth's atmosphere.
- Encourage students to think about how Earth's crust continuously forms and moves according to the well-established theory of plate tectonics. Do students realize that the Earth doesn't get larger? Therefore, the same amount of crust must subduct (melting into the mantle) as what forms (during volcanic eruptions and seafloor spreading). When crust subducts, anything, including fossil remains, stored within that material melts into the mantle and is lost from scientific study. Ask students to think about gaps in scientific knowledge related both to fossil evidence and other areas of study.

Extend

Offer students other ways to explore the content of the article as it relates to your curriculum, such as:

FOLLOWING THE PLOT

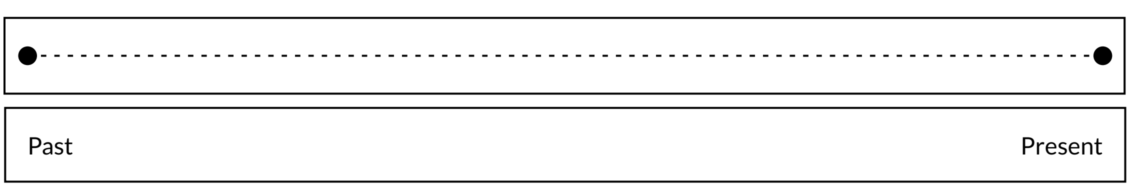
- **Purpose:** Students will create a story plot of the Earth's history. Throughout the process, they will draw parallels between the structure of literature and the history of the Earth.
- **Note to teacher:** You can adjust this activity for the time available by limiting the number of events students include. For a refresher on plot diagrams, see this helpful Powerpoint presentation from the Alabama Learning Exchange. Depending on the level of your students, you might also consider asking the students to practice by creating plot diagrams for a favorite television show, a song or a story they recently read in class.
- **Materials:** Whiteboard or chalkboard, dry-erase markers or chalk, square pieces of construction paper, tape
- **Procedures:**
  1. Hand out Blackline Master #4 and, if your students are not familiar with plot diagrams, discuss the idea of story plots.
  2. Ask students to read the story "Earth's (Not So Boring) Boring Billion" and identify elements of Earth's history that tell the story of Earth. Have them write each event on a separate piece of construction paper. Instruct students to use construction paper colors with a purpose. For example, they might choose to use the same color for events that happened close in time, or they might choose to organize the events according to the type of plot element (all plot twists in purple, for example).
  3. Ask students to research additional events that cover the period from Earth's boring billion to today and record them in the same way.
  4. Have students arrange the historic events (the squares of construction paper) in order on the whiteboard or chalkboard with the oldest events on the left and the most recent on the right.
  5. Ask students to use the information they have uncovered to create a narrative arc that connects the events and highlights the emerging plot of Earth's story. To help students visualize the connection between historic events and the plot twists akin to literature, students can position events vertically on the board to depict rising action, plot twists, the climax and other story elements. When completed, a student can draw a line connecting all the elements.
  6. Finally, students can compare and contrast the story plot they have diagrammed for Earth with common story structures found in literature. You might have students consider the idea of a resolution. Does Earth's story have a resolution? If not, would this be considered a "cliff-hanger" or can students imagine what the resolution might look like given existing knowledge?

MAPPING DATA

- **Purpose:** Students will create a model that reflects geologic and biologic evidence related to the origin of Earth and how our planet has changed over time.
- **Notes to teacher:** The listing of data to be mapped in Blackline Master #5 is only a place to start. Students can add more information as time allows or some of these elements can be eliminated. If you'd like to make the activity more challenging, you can ask your students to do their own research on the geological divisions of time (eras and periods) and ask them to incorporate these timeframes into their timeline.

  The events provided are not organized chronologically. This will help students begin by thinking about this challenge.

  Students may want to use the graphic from the article on Page 20 of the story to help them visualize their design and gain information to add to their timelines.
- **Materials:** Rolls of cash register tape, metric rulers, colored pencils, glue, scissors
- **Procedures:**
  1. Give each student (or pair of students) a copy of Blackline Master #5. Have them determine which information came from the article and highlight those items. Then, give students the remaining materials for building their timeline.
  2. Have students determine the scale they will use for their timeline (the ratio of millions of years to space). One choice is to give a formula (if 1 million years = 1 millimeter, then students will need a piece of cash register tape 5 meters long). Another option is for the students to choose the length of cash register tape and develop their own scale (this second option is more challenging).
  3. Have students mark the cash register tape with equidistant markings to represent each hundred million years.



4. Students should determine which end of the tape represents the past and which represents the present.
5. Encourage students to plan how they will organize information on their timelines. Should all events be represented the same way? Should geological events and biological events appear differently? Encourage students to use what they know about note-taking (use of color, space and line). They might decide to represent some events as images rather than in words. If students are representing periods of time, they will have to decide how to approach that task.
6. Students record their data on the cash register tape. Each item is in number of years before the present. Remind students to count from the present into the past.
7. To evaluate, students can peer-correct timelines by checking for measurement accuracy, completeness and placement of data.

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Vocabulary Support

Directions: You can use a graphic organizer like the one below to help you understand scientific terms and concepts that you don't already know. Create a branching diagram like this for each word you want to explore.

Word or phrase

Definition

How it is used in the text

What it means to me

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Figurative Language

Directions: Below are types of figurative language. Try to find an example of each in the article. Where you can't find a direct quote, see if you can change a phrase from the article to become an example of that type of language.

Type of figurative language	Definition of the term with an example	Example based on the text	Edited text or direct quote?
Alliteration	Using words that begin with the same sound. "I'll kill him though," he said. "In all his greatness and his glory." —*The Old Man and the Sea* by Ernest Hemingway		
Metaphor	Portrayal of a person, place, thing, action or feeling as something else. "You're a falling star, you're the getaway car." —"Everything" by Michael Bublé		
Paradox	The juxtaposition of seemingly contradictory concepts that reveal an unexpected truth. "Life is a preparation for the future; and the best preparation for the future is to live as if there were none." — Attributed to Albert Einstein		
Personification	Giving human characteristics to something not human. "The sun smiled down on her."		
Pun	A play on words. "You can tune a guitar, but you can't tuna fish. Unless of course, you play bass." —Attributed to Douglas Adams		
Antithesis	Putting two ideas against each other in a balanced way. "One small step for man, one giant leap for mankind." —Neil Armstrong		

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Comprehend

After reading the article "Earth's (Not So Boring) Boring Billion," answer these questions:

1. **What is the main topic of the article?**

2. **Why was the interval between 1.8 and 0.8 billion years ago considered the "dullest time in Earth's history"?**

3. **How did the "boring billion" end?**

4. **Name a reason from the article to explain why scientists study Earth's history?**

5. **Why was the study of the breadcrumb sponge important?**

Analyze

Use what you already know about the topic, as well as what you learned in the article "Earth's (Not So Boring) Boring Billion," and answer these questions:

1. **What is the difference between eukaryotes and the life that evolved before them, called prokaryotes?**

2. **What is the significance of chromium-53 and why is it different from other forms of chromium?**

3. **The article quotes one scientist who has changed his thinking about the strength of the role of plate tectonics in the development of Earth's atmosphere. What types of events have changed the chemistry of Earth's atmosphere in the past?**

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Following the Plot

Directions: A story graph is a graphic organizer that you can use to keep track of the ideas from the article, "Earth's (Not So Boring) Boring Billion." Create your own story graph based on events from the article and your personal knowledge of Earth's history. You may have many plot twists to your story. Consider how it will end. Will it end in the present or will you project your ideas into the future?

Climax

Plot twist

Plot development

Plot twist

Preamble

Resolution

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Mapping Data

Directions: Listed below are various biological and geological events that should appear on your timeline. Once you have read through the items and highlighted the ones from the article "Earth's (Not So Boring) Boring Billion," use your scale to convert the years into millimeters. Then create your timeline.

1. The Earth forms out of a cloud of gas and dust, 4.6 billion years ago

   = ___________ mm

2. A Mars-sized rock rips off a piece of the young planet, creating the moon 4.5 billion years ago

   = ___________ mm

3. Oxygen accumulates in the atmosphere in the Great Oxidation Event, 2.4 billion years ago

   = ___________ mm

4. *Brontosaurus*, sometimes considered an *Apatosaurus*, evolved, 150 million years ago

   = ___________ mm

5. Climate stabilized during the "boring billion," 1.8 billion years ago to 0.8 billion years ago

   = ___________ mm

6. Eukaryotes appear, possibly as early as 1.8 billion years ago

   = ___________ mm

7. Start of the Quaternary glaciations, 2.6 million years ago

   = ___________ mm

8. Early jawed fish appear, 420 million years ago

   = ___________ mm

9. Early evidence of cyanobacteria, the earliest photosynthetic microbes, 2.5 billion years ago

   = ___________ mm

10. First evidence of amphibians, 365 million years ago

    = ___________ mm

11. Early evidence of angiosperms (flowering plants), 125 million years ago

    = ___________ mm

12. First evidence of dinosaurs, 230 million years ago

    = ___________ mm

13. First evidence of a horse, 55 million years ago

    = ___________ mm

14. First land plants, 450 million years ago

= ___________ mm

15. Reptiles appear, 310 million years ago

= ___________ mm

16. Earliest evidence for sponges, about 650 million years ago

=___________ mm

17. First prokaryotes, 3.5 billion years ago

= ___________ mm

18. Early trilobites, 500 million years ago

= ___________ mm

19. Oldest known rocks, 3.9 billion years ago

= ___________ mm

20. *Tyrannosaurus rex* appeared, 68 million years ago

= ___________ mm

21. First bird, 150 million years ago

= ___________ mm

22. Humans' distant relatives split from an apelike ancestor, 13 million years ago

= ___________ mm

23. *Homo* genus shows up in Africa, 2.8 million years ago

= ___________ mm

24. The breakup of the supercontinent Pangaea began, 200 million years ago

= ___________ mm

25. The end of "Snowball Earth," 635 million years ago

= ___________ mm

26. Permian extinction, the worst mass extinction in Earth's history, 252 million years ago

= ___________ mm

27. Death of the dinosaurs, 65 million years ago

= ___________ mm

28. Supercontinent Nuna assembled and broke up, 1.6 billion to 1.3 billion years ago

= ___________ mm