ScienceNews
EDUCATOR GUIDE

HHMI Tangled Bank Studios

December 7, 2019

Here Come the (Bigger) Mammals

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

About this Guide

This Guide, based on the *Science News* article "Here come the (bigger) mammals," asks students to analyze a graph about a recent fossil find, discuss how organisms evolve as ecosystems change and research important fossil sites across the world.

This Guide includes:

Article-based Comprehension Q&A — These questions, based on the *Science News* article "Here come the (bigger) mammals," Readability: 9.8, ask students to analyze what a recent fossil discovery tells scientists about the recovery of mammals after an asteroid struck Earth. Related standards include NGSS-DCI: HS-LS2; HS-LS4; HS-ESS2.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will explore the immediate and long-term effects of specific environmental disturbances, including how energy enters or leaves an ecosystem, how the biotic and abiotic characteristics of the ecosystem change and how organisms evolve under the new conditions. Related standards include NGSS-DCI: HS-LS2; HS-LS4; HS-PS3; HS-ESS2.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Activity: Stories in Rock

> **Summary:** In this activity, students will research important fossil sites across the world and synthesize what they find into a story to present to the class. Related standards include NGSS-DCI: HS-LS2; HS-LS4; HS-ESS2.
>
> **Approximate class time:** 2 class periods to complete the discussion, research and reporting and to debrief as a class.

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Article-based Comprehension, Q&A

Directions for teachers: After your students read the print version of the *Science News* article "Here come the (bigger) mammals" (Readability: 9.8), ask them to answer the following questions.

1. What event altered life on Earth 66 million years ago? What may have been a major consequence of the event?

An asteroid struck Earth, which is believed to have killed off all of the dinosaurs except those that evolved into birds.

2. What have scientists found in rocks in Colorado? How are these discoveries helping scientists understand the life-altering event?

Scientists found a cache of plant and mammal fossils from after the asteroid strike. The fossils are helping scientists understand how plants and mammals recovered from the asteroid strike and flourished over time.

3. According to the article, how did mammals change in the hundreds of thousands of years after the event? What factors may have contributed to that change?

Mammals evolved bigger maximum body sizes after the asteroid strike. Scientists think that a lack of large predators and an explosion of plant diversity may have contributed to the change.

Reading graphs

4. On the graph "How fast mammals grew in maximum body mass after the dino-killing asteroid," what information is displayed on the x-axis? What about the y-axis? Don't forget to include units!

The x-axis shows maximum mammalian body mass in kilograms. The y-axis shows the number of years before and after an asteroid struck Earth 66 million years ago.

5. What does the horizontal red line represent?

The red line represents the asteroid impact that wiped out nonavian dinosaurs 66 million years ago.

6. What does the thick beige line show? What about the numbers on the line?

The beige line represents how mammals evolved in size, indicated by body mass, from before the asteroid impact to 1 million years after the strike. The numbers are examples of mammal species along that evolutionary path, and the colors of the numbers indicate the location where each fossil was found.

7. What do the horizontal dotted lines represent? Explain each line shown. Why do you think the lines are included on the graph?

The dotted lines represent major developments in plant life. Soon after the asteroid impact, ferns were the dominant plant. By about 300,000 years after the impact, palms dominated. And nearly 700,000 years after the impact, legumes appeared. Plants might be included on the graph to give added context. Changes in plant diversity after the strike may be related to the evolution of mammals.

8. Describe fossil No. 1 on the graph. Where was it found? What mammal does it represent? How big was this mammal? And how does it differ from the other mammals shown on the graph?

Fossil 1 is *Didelphodon* and was found in North Dakota. It had a body mass of a little less than 10 kilograms. *Didelphodon* is the only mammal from before the asteroid strike shown on the graph and the only one shown that was not found in Colorado.

9. How does the body mass of *Baioconodon* compare with the body mass of *Didelphodon*? According to the beige line, how do these mammals' body masses compare with the body masses of mammals that survived the strike?

Baioconodon (which lived roughly 100,000 years after the strike) and *Didelphodon* have similar body masses. The biggest mammals from just after the strike had a much smaller body mass.

10. Based on the comparison you made in the previous question, come up with a hypothesis about mammals' recovery from the asteroid strike.

It took about 100,000 years for mammals' body mass to rebound from the strike.

11. According to the graph, what were the body masses of the mammals found in Corral Bluffs, Colo.? How do these mammals differ from the mammal found in South Table Mountain, Colo.?

By about 500,000 years, *Carsioptychus* had a body mass of about 25 kilograms. By about 700,000 years, *Eoconodon* had a body mass of nearly 50 kilograms. These mammals lived hundreds of thousands of years after and had much larger body masses than *Baioconodon*.

12. What is one conclusion that you can draw from the graph? Explain.

Mammals' body mass increased over hundreds of thousands of years after the asteroid strike. About 700,000 years after the strike, the biggest mammals' body mass was nearly five times that of the biggest mammals' body mass prior to the strike. The asteroid strike changed the environment in ways that made it possible for mammals to grow.

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Student Comprehension Worksheet

Directions: After reading "Here come the (bigger) mammals," answer the following questions.

1. What event altered life on Earth 66 million years ago? What may have been a major consequence of the event?

2. What have scientists found in rocks in Colorado? How are these discoveries helping scientists understand the life-altering event?

3. According to the article, how did mammals change in the hundreds of thousands of years after the event? What factors may have contributed to that change?

Reading graphs

4. On the graph "How fast mammals grew in maximum body mass after the dino-killing asteroid," what information is displayed on the x-axis? What about the y-axis? Don't forget to include units!

5. What does the horizontal red line represent?

6. What does the thick beige line show? What about the numbers on the line?

7. What do the horizontal dotted lines represent? Explain each line shown. Why do you think the lines are included on the graph?

8. Describe fossil No. 1 on the graph. Where was it found? What mammal does it represent? How big was this mammal? And how does it differ from the other mammals shown on the graph?

9. How does the body mass of *Baioconodon* compare with the body mass of *Didelphodon*? According to the beige line, how do these mammals' body masses compare with the body masses of mammals that survived the strike?

10. Based on the comparison you made in the previous question, come up with a hypothesis about mammals' recovery from the asteroid strike.

11. According to the graph, what were the body masses of the mammals found in Corral Bluffs, Colo.? How do these mammals differ from the mammal found in South Table Mountain, Colo.?

12. What is one conclusion that you can draw from the graph? Explain.

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Cross-curricular Discussion, Q&A

Directions for teachers:

After reading the article "Here come the (bigger) mammals" (Readability: 9.8), use the following prompts to discuss how the asteroid impact believed to be responsible for the demise of the dinosaurs altered Earth's ecosystems and shaped the evolution of life. After completing the prompts for the asteroid impact, choose another environmental disturbance for your students to explore — or encourage students to choose their own. Depending on your teaching needs, consider examples that differ in type (the introduction of an invasive species, or the flooding of a valley) or scale (a local wildfire, or the effects of global warming). You can use the *Science News* archive to search for specific examples.

The disturbance

1. What was the disturbance?

2. Where did it begin?

3. How far did it spread?

4. How long did it last?

Immediate impact

5. What were the immediate abiotic effects of the disturbance? Consider, for example, how the disturbance transferred energy into, out of or within the system? How did the disturbance change the soil, water or air quality? Did it lead to immediate changes in temperature or precipitation? Did it change the availability of any ecosystem resources? What other effects on the physical environment can you identify?

6. What were the immediate biotic effects of the disturbance? Consider, for example, what types of organisms might have suffered most from the disturbance and why. Would you expect the population size of any organisms to be immediately affected? If so, which ones? What about the carrying capacity? Explain. Are there organisms that weren't affected, or were positively affected? Why or why not?

7. Based on your answers above, how would the biodiversity of the ecosystem differ immediately following the disturbance? What about the quantity and distribution of organisms at various trophic levels (decomposers, producers, primary consumers, secondary consumers and so on)? Which level might be impacted the most?

8. Does the impact at the site of the disturbance differ from the impact on the surrounding environment? If so, how? How might the effects vary with distance from the disturbance?

Cascading effects

9. What effects might follow from the immediate effects described above? Of all the effects discussed, which would have repercussions beyond the end of the disturbance — for decades, centuries or even millennia? Be sure to think about the biotic and abiotic effects.

10. What ecological niches may become available due to the disturbance? Explain. What types of organisms would you expect to first dominate the newly available niches? Draw a graph indicating how the population size of an organism first dominating a new niche would likely change over time. Think about available resources, possible competition and predation, and how these factors would affect and be affected by the population size. Explain your answer.

11. Based on the quantity and distribution of organisms at various trophic levels following the disturbance, how would the composition of the community change over time? Explain what types of organisms would be most successful right after the disturbance, and how and why those organisms might be succeeded by others over time.

12. In what ways might the disturbance drive evolution over time? Explain.

Recovery

13. How would you define “recovery” for a disturbed ecosystem?

14. Based on your definition, can disturbed ecosystems ever “recover”?

15. For conservationists trying to restore or revive ecosystems after a disturbance, what might success look like?

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Student Discussion Worksheet

Directions:

Read the article "Here come the (bigger) mammals," and use the following prompts to discuss how the asteroid impact believed to be responsible for the demise of the dinosaurs altered Earth's ecosystems and shaped the evolution of life. After discussing the asteroid impact, use the prompts to consider another environmental disturbance, as instructed by your teacher.

The disturbance

1. What was the disturbance?

2. Where did it begin?

3. How far did it spread?

4. How long did it last?

Immediate impact

5. What were the immediate abiotic effects of the disturbance? Consider, for example, how the disturbance transferred energy into, out of or within the system? How did the disturbance change the soil, water or air quality? Did it lead to immediate changes in temperature or precipitation? Did it change the availability of any ecosystem resources? What other effects on the physical environment can you identify?

6. What were the immediate biotic effects of the disturbance? Consider, for example, what types of organisms might have suffered most from the disturbance and why. Would you expect the population size of any organisms to be immediately affected? If so, which ones? What about the carrying capacity? Explain. Are there organisms that weren't affected, or were positively affected? Why or why not?

7. Based on your answers above, how would the biodiversity of the ecosystem differ immediately following the disturbance? What about the quantity and distribution of organisms at various trophic levels (decomposers, producers, primary consumers, secondary consumers and so on)? Which level might be impacted the most?

8. Does the impact at the site of the disturbance different from the impact on the surrounding environment? If so, how? How might the effects vary with distance from the disturbance?

Cascading effects

9. What effects might follow from the immediate effects described above? Of all the effects discussed, which would have repercussions beyond the end of the disturbance — for decades, centuries or even millennia? Be sure to think about the biotic and abiotic effects.

10. What ecological niches may become available due to the disturbance? Explain. What types of organisms would you expect to first dominate the newly available niches? Draw a graph indicating how the population size of an organism first dominating a new niche would likely change over time. Think about available resources, possible competition and predation, and how these factors would affect and be affected by the population size. Explain your answer.

11. Based on the quantity and distribution of organisms at various trophic levels following the disturbance, how would the composition of the community change over time? Explain what types of organisms would be most successful right after the disturbance, and how and why those organisms might be succeeded by others over time.

12. In what ways might the disturbance drive evolution over time? Explain.

Recovery

13. How would you define "recovery" for a disturbed ecosystem?

14. Based on your definition, can disturbed ecosystems ever "recover"?

15. For conservationists trying to restore or revive ecosystems after a disturbance, what might success look like?

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Activity Guide for Teachers: Stories in Rock

Directions for teachers:

Explain to students that scientists aim to understand current natural phenomena and the past. This is true, for example, for paleontologists, who study fossils to try to understand the history of life on Earth. Fossil sites around the world tell stories that are rooted in time and place and preserved in the ground. Fossils, for example, can provide clues to the organisms that once lived on Earth, their abundance, distribution, diet, lifestyles and evolution over time. Fossil sites also offer clues to past climate and major geological and ecological events.

Before students begin the activity they should read the *Science News* article "Here come the (bigger) mammals," or the online versions of the story at *Science News* or *Science News for Students*.

Class discussion questions
Begin by going over the discussion questions that follow as a class. These questions will help students understand how a site can tell a story.

1. What types of fossils have been discovered at Corral Bluffs in Colorado?

Scientists have found fossils of plants and mammals there, including mammal skulls.

2. When do these fossils date from?

The fossils date to the demise of the dinosaurs and the million or so years that followed, roughly 66 million to 65 million years ago.

3. Based on the article, why are the fossil discoveries at Corral Bluffs important to the field of paleontology?

The fossils provide a window into the recovery and flourishing of plants and mammals in the years after the demise of the dinosaurs.

4. What story does the site tell?

The fossils discovered at the site reveal that mammals were able to grow much bigger after the nonavian dinosaurs died out. Evidence shows that there was a large variety of plant life and few predators, which allowed mammals to grow to large sizes in a relatively short time frame.

Researching the fossil sites
Now have your students form pairs or small groups and assign each a different fossil site. The groups should research their fossil site and answer the student questions provided. Students will then synthesize their answers into a story the site tells about the history of life on Earth.

Possible sites include:

South Africa's Cradle of Humankind (Pliocene, up to 3.5 million years ago)
Hundreds of fossils of the ancestors of modern humans have been found in the limestone caves around Johannesburg, South Africa, including the first species to establish that early humans lived in Africa. A child's skull, dubbed the Taung child, was discovered here in 1924. It was the first fossil found of *Australopithecus africanus*, which walked upright and had both human- and ape-like features. This site is home to roughly 40 percent of all the hominid fossils yet discovered. In 1999, it was declared a World Heritage Site for its importance in revealing humanity's origins.

Egypt's Wadi Al-Hitan (Middle to Upper Eocene, 41 million to 34 million years ago)
Also known as "Whale Valley," this site in the desert west of Cairo, was a shoreline during the Eocene. The site contains fossils of the earliest whales (now extinct). Wadi Al-Hitan tells the tale of land mammals evolving into large ocean mammals. In 1990, scientists unearthed ankle, foot and toe bones here, showing that these early whales still had feet. In modern whales, the limb bones are now vestigial — small and not functional.

Germany's Messel Pit (Eocene, 48 million to 47 million years ago)
This site, a former oil shale mine, is significant because it has exceptionally well-preserved fossils of more than a thousand species of plants and animals from the Eocene Epoch. Some specimens include entire skeletons, feathers, skin, hair and even stomach contents. The fossils provide the clearest picture of the early evolution of modern mammals. During this time, mammals became firmly integrated into the various land ecosystems of the day.

Montana's Hell Creek Formation (66 million years ago)
Today, this fossil-rich formation lies in the dusty badlands of Montana, Wyoming and North and South Dakota. But the clay, mudstone and sandstone that make it up were deposited in rivers and deltas on the shore of an interior seaway at the end of the age of dinosaurs. The formation preserved a range of plants and animals —including many large-bodied Late Cretaceous dinosaurs like *Tyrannosaurus rex* and *Triceratops* — along with some evidence of their demise. The formation holds a layer of space dust from the asteroid that struck Mexico's Yucatan Peninsula triggering the global mass extinction that brought an end to the Cretaceous. Another fossil site in the formation, in North Dakota, may even record the events of the day of the impact.

England's Jurassic Coast (Mesozoic, 252 million to 66 million years ago)
Stretching across 95 miles of the southwest coast of England are fossil beds that hold a near-continuous 186-million-year record of the evolution of life in the Triassic, Jurassic and Cretaceous periods. The sediments, deposited on the bottom of a Mesozoic sea, include thick beds of white chalk and red sandstone that now form cliffs towering over the English Channel. Coastal waves continually batter the cliffs, eroding them and exposing new fossils. The site is famous for the early 19th century discoveries of the fossils of large marine reptiles *Ichthyosaurus* and *Plesiosaurus* by fossil collector and paleontologist Mary Anning.

Canada's Burgess Shale (Middle Cambrian, 510 million to 505 million years ago)
The Burgess Shale, located in the Canadian Rocky Mountains, is famous for its fossils of soft-bodied animals, which are rarely preserved in the rock record. The animals, including worms, sponges and arthropods, lived on the seafloor at the base of a slope and were buried by a sudden mudslide. The fossils reveal an entire marine community that lived near the equator during the Cambrian Explosion — a time when most of the major animal groups first appeared. Because the site provides rare and valuable

information about a significant event in the evolution of life on Earth, it has been designated a World Heritage Site.

Australia's Ediacara Hills (Late Precambrian, 560 million to 543 million years ago)
Even in Charles Darwin's time, scientists knew that simple animals must have existed prior to the Cambrian Explosion. A few fossils were occasionally found in older rocks from the Precambrian, the period of Earth's history before 542 million years ago, but they were inconclusive. Then, in 1946, the largest, best-preserved group of Precambrian fossils was found in the Ediacara Hills in Australia. The fossils were simple, just blobs and disks, but they had a wide range of characteristics. Some represent entirely extinct groups. But others could be ancestors of the modern animal groups that arose in the Cambrian.

Poster board and presentations
Each small group should prepare a poster board and a two-minute oral presentation describing the location of the site, the fossils found there and the story the site tells. The groups should mark the location of the sites on a world map. Consider having students set up the poster boards as "museum exhibits" in the library or classroom. The rubric below (out of a total 100 points) can help you evaluate each group's poster and oral presentation.

Location of site on the world map (10 points)

Poster (45 points)
-Is the location of the site expressed in words and/or maps? (5 points)
-Are there at least four images of the fossils? (5 points)
-Does each image have its own description? (5 points)
-Does the poster explain the types of fossils found — organisms, number of fossils, variety of fossils and so on? (10 points)
-Was the location of the site described as it appeared at the time the fossils were formed? (5 points)
-Was the location of the site described as it appears now? (5 points)
-Does the poster present a cohesive story about the site and its significance? (10 points)

Oral presentation (45 points)
-Were the number of fossils, varieties of fossils and the organisms found described? (10 points)
-Was the location of the site described as it appeared at the time the fossils were formed? (5 points)
-Was the location of the site described as it appears now? (5 points)
-Did the group explain how researchers interpreted the findings at the site? (5 points)
-Did the group express how the findings at the site confirmed, changed or led to new ideas or theories about the history of life? (5 points)
-Did the group tell a story about their site (give a setup, rising action, a climax and a resolution)? (5 points)
-Did each member of the team contribute to the presentation? (5 points)
-Did the group complete its presentation in the time allotted? (5 points)

Debrief as a class
After students have the chance to hear about each other's sites, have them answer questions 12 to 17 to debrief as a class. These questions ask students to compare fossil sites and think about how stories from multiple sites can combine to tell a broader story about the history of Earth and life on Earth.

SN EDUCATOR GUIDE

December 7, 2019

Here Come the (Bigger) Mammals

Activity Guide for Students: Stories in Rock

Directions for students:

Paleontologists uncover fossils that can shape our understanding of the past. Some sites, including Corral Bluffs in Colorado, provide so many fossils that they tell entire stories about a particular time or place. Together, those stories offer a fuller, though often still incomplete, picture of the major changes in the history of Earth and its life. Now it is your turn to use facts to put together a story.

In your small group, you will explore another important fossil site and use what you find to piece together the story of that particular time and place. Once you have completed your research, you will plot your site on the class world map, create a poster board of your findings and present your story to the rest of the class. When you are preparing your stories, remember that a story is more than just reciting the facts. Think about where your site fits in place and time. Think about what information can be inferred from your research. Think about the story arc. Is there a setup, rising action, a climax and a resolution?

Researching your fossil site
Research information about your site to answer the following questions. Keep in mind that some answers may not be known for every site.

1. What is the fossil site your team will be researching?

2. What is the location of the site? Be sure to mark it on the classroom's world map. You will receive credit for marking this location correctly.

3. What does the area look like now? What is the area's current climate?

4. What events led to the fossilization of the organisms found at the site? Make sure to provide details that paint a picture of what happened there.

5. How does the fossil site provide a glimpse into the geological history of the site? How has the area changed over time?

6. How many fossils were found at your site? What organisms are represented? Are they all the same type, or were there many different varieties of fossils found there?

7. What time period do the fossils of the site cover?

8. How do the types and variety of fossils offer a glimpse into the history of the site at the time the fossils were formed?

9. If the climate is different currently from what it was at the time of the fossil formation, what possible reasons are there for the difference?

10. Why is the site important?

11. How might the site fit into a bigger picture? Does it reveal anything about the larger historical events on Earth?

Creating your poster board

Your poster board is a visual representation of your site's story. Include at least four images of fossils found at the site (make sure you are choosing the most important ones and that you include credits for images). Include a description of each fossil you choose, explaining what it is and why it is important to the site's story. Be sure to incorporate the answers to your research questions into the historical story your site tells.

Your group will be graded on how well your poster addresses the following questions:

-Is the location of the site expressed in words and/or maps?
-Are there at least four images of the fossils?
-Does each image have its own description?
-Does the poster explain the types of fossils found — organisms, number of fossils, variety of fossils and so on?
-Was the location of the site described as it appeared at the time the fossils were formed?
-Was the location of the site described as it appears now?
-Does the poster present a cohesive story about the site and its significance?

Preparing your presentation
Based on your research, prepare a two-minute presentation with your group that tells your site's story. This should be something that your research team can present to others. Be sure to incorporate the answers to your research questions.

Here are a few tips on creating your presentation:
-Use descriptive language.
-Keep track of the resources and references you are using so you can easily cite them at the end of your project.
-Practice telling your story as a group, making sure each group member has a defined and equal role in the presentation.

Your group will be graded on how well your presentation addresses the following questions:

-Were the number of fossils, varieties of fossils and the organisms found described?
-Was the location of the site described as it appeared at the time the fossils were formed?
-Was the location of the site described as it appears now?
-Did the group explain how researchers interpreted the findings at the site?
-Did the group express how the findings at the site confirmed, changed or led to new ideas or theories about the history of life?
-Did the group tell a story about their site (give a setup, rising action, a climax and a resolution)?
-Did each member of the team contribute to the presentation?
-Did the group complete its presentation in the time allotted?

Debrief as a class
After viewing all of the presentations, answer the following debriefing questions.

12. Which of the sites have overlapping stories — because they cover a shared time period, place or feature fossils from related organisms? Make sure to include evidence to support any claims that you make.

13. Which of the other fossil sites is most complementary to yours? Explain.

14. Describe the similarities and differences between your site and the complementary site.

15. How does the complementary site you chose add to, support or conflict with the story at your original site?

16. How do the stories from all of the individual sites combine to tell a broader story about the history of Earth and life on Earth?

17. What questions can be answered by combining data from these sites? What questions can't be answered, and what additional data is needed?