

Lesson 5: Mass Extinction

In this lesson, students will learn about the causes of the “Big 5” mass extinctions that have occurred throughout Earth’s history and the effects on biodiversity over time.

Student objectives:

Students will be able to:

- ▶ List the five major extinction events in Earth’s history
- ▶ Compare the different extinction events in terms of causes and the effects on global biodiversity
- ▶ Calculate the marine biodiversity losses and gains surrounding extinction events
- ▶ Construct an argument based on evidence in support of or against the 6th Mass Extinction
- ▶ Extrapolate what would happen if the 6th Mass Extinction were to occur
- ▶ Devise potential solutions to slow down current extinction rates.

NGSS: MS-LS1-4, 2-4, 4-1; MS-ESS2-2, 3-2

Materials: Extinction Worksheets, Access to computers/tablets and the internet, arts and crafts supplies for creating posters (optional)

Time: 3 class periods

Information relevant to extinction events for teachers:

Approximately 99.9% of all life that ever lived on Earth is now extinct. However, extinction rates have not been constant throughout geologic time. Depending on the criteria used, scientists estimate there have been anywhere from five to twenty extinction events in the Earth’s history. When determining whether or not an extinction event has occurred, scientists often look to the marine fossil record because marine fossils have better preservation and a wider stratigraphic range compared to the terrestrial record. During an extinction event, there is a rapid, widespread decrease in biodiversity on the planet. Although extinction events eliminate a large number of species on the planet, they also make way for new and different species to arise. In 1982, Jack Sepkoski and David M. Raup published a landmark paper where they identified five mass extinctions. These were originally thought to be outliers; however, improved statistical tests have revealed that animal life on Earth has experienced at least five major and many minor extinction events. The “Big 5” extinction events are as follows:

1. **End Ordovician Extinction:** 443 million years ago. This is a series of two extinctions that occurred a million years apart and eliminated approximately 85% of marine life at the time. It is believed that climate change in the form of a major ice age played a role in these extinctions.

2. **Late Devonian Extinction:** 385-365 million years ago. Near the end of the Devonian Period, there were a series of three extinction events, each separated by 10 million years. Only the event occurring at 375 million years ago is large enough to be considered part of the Big 5. This extinction was most prominent in tropical seas where many corals, sponges, brachiopods, and trilobite genera went extinct. It is believed that a cooling climate played a role in this extinction event.
3. **End Permian Extinction:** 252 million years ago. This was the largest extinction event in the history of life. Up to 75% of marine genera were lost along with up to 70% of terrestrial vertebrates. Warming of the Earth's climate caused by massive volcanism emitting carbon dioxide into the atmosphere and associated changes to oceans were the most likely causes of the extinction.
4. **End Triassic Extinction:** 201 million years ago. Like the End-Permian extinction, climate change brought on by global warming is believed to be responsible for the major drop in biodiversity that saw extinctions both in the sea and on land. This event paved the way for dinosaurs to dominate the landscape.
5. **End Cretaceous Extinction:** 66 million years ago. This is the extinction event that wiped out all dinosaurs except birds. This event also wiped out flying and swimming reptiles, and important marine invertebrates. There are multiple lines of evidence to suggest that an asteroid as big as 6 miles across struck the planet near what is today the Yucatan Peninsula in Mexico. This impact would have created an enormous cloud of dust and debris that would have limited sunlight and thus disrupt the food chain. Also occurring at the time was increased volcanism in present-day India that may have also altered the climate.

Suggested procedure:

Engage:

- Ask the class to brainstorm ideas about what killed the dinosaurs (except birds).
- As students come up with suggestions, the teacher should write them on the white board
- Next, inform the class that 99% of all life that ever existed has gone extinct.
 - o What does the class think about that fact?
 - o What might have caused these other extinctions?
 - o A mass extinction is an event that happens when a large number of species die over a short period of geological time, how often do you think these mass extinctions, like the one at the time of the dinosaurs, occur?
- Show the class the following video: What Really Killed the Dinosaurs? (10m 44s) <https://youtu.be/1iNcRJGzzxs>
 - o Were there any possible causes that students did not initially come up with?
 - o Is it possible that these types of events could have happened at other times in the past? What about today?
- o Is it possible that these types of events could have happened at other times in the past? What about today?

Explore:

- Divide the class into five groups. Each group will investigate one of the “Big 5” mass extinctions that have happened in Earth’s history. These extinctions are named after the geologic time periods when they occur. These events include:
 - o End Ordovician (pronunciation: or-duh-VI-shn)
 - o Late Devonian (pronunciation: div-OH-nee-uhn)
 - o End Permian (pronunciation: PUR-mee-uhn)
 - o End Triassic (pronunciation: trai-A-suhk)
 - o End Cretaceous (pronunciation: kruh-TAY-shuhs)
- Give each group the worksheet for a different mass extinction.
- Note: Students will use the Earth Viewer web application from HHMI Biointeractive to complete this activity. If this is your first time using this application, go through the tutorial with the class. Show students how to manipulate the virtual globe, view different time periods, and select the “Mass Extinctions” options from the “view” tab.

Explain:

- Have each group create a newscast, poster, poem, or play from the perspective of the survivors of their mass extinction. Each project should include:
 - o When the event occurred
 - o What percentage of organisms went extinct during the event
 - o What types of organisms went extinct
 - o What caused the mass extinction
 - o What organisms survived and what new organisms appeared after the event
- Each group should present their final product to the class

Elaborate:

- Some scientists think that we are now experiencing the 6th mass extinction. Play the following videos for the class:
 - o The Sixth Extinction (start at 3m 27s)
<https://youtu.be/z9gHuAwxwAs?t=207>
 - o Who Will Survive The 6th Mass Extinction? (3m 50s)
<https://youtu.be/XdkSo6UqiPA>
- Use the following prompts to either for a class discussion or as a writing assignment that is supported by what students have learned about previous mass extinctions:
 - o Why do scientists think we are experiencing another mass extinction right now? Do you agree with that assessment? Why or why not?
 - o What similarities or differences do you notice between modern changes and the past mass extinctions?
 - o What do you think life would be like after the next mass extinction? Which organisms would survive, and which would go extinct? What do you think the next dominant species on the planet would be?
 - o What do you think could be done to slow down or prevent the next mass extinction? Do you think it is avoidable? Why or why not?

Evaluate:

- Answer keys are provided for the worksheets
- Student presentations should demonstrate an understanding of their extinction event and should include the information listed in the Explain section

Name: _____

Date: _____

End Ordovician Extinction

Directions: Use the Earth View web application by HHMI Biointeractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-ordovician-extinction/>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Ordovician Period
2. Compare what the planet looked like at the beginning of the Ordovician and the end. Do you notice any major changes? What do you see?
3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Ordovician?
4. How long was a day during the Ordovician Period?

Name: _____

Date: _____

5. What caused the extinction event at the end of the Ordovician Period?

6. What types of animals went extinct at the end of the Ordovician? Which ones survived?

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Ordovician Period and the Silurian Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning	# Marine Genera at End
Ordovician	488.3	443.7	284	1358
Silurian	443.7	416.0	838	1261

7. How long was the Ordovician Period?

8. What percent of genera was lost from the end of the Ordovician to the beginning of the Silurian Period?

9. What percentage of genera was gained during the Silurian Period?

10. Did the number of genera recover by the end of the Silurian?

Name: _____

Date: _____

End Devonian Extinction

Directions: Use the Earth Viewer web application by HHMI Biointeractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources including the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/late-devonian-extinctions/>) or PBS (<https://www.pbs.org/wgbh/evolution/change/deeptime/devonian.html>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Devonian Period
2. Compare what the planet looked like at the beginning of the Devonian and the end. Do you notice any major changes? What do you see?
3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Devonian?
4. How long was a day during the Devonian Period?

Name: _____

Date: _____

5. What caused the extinction event at the end of the Devonian Period?
6. What types of animals went extinct at the end of the Devonian? Which ones survived?

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Devonian Period and the Carboniferous Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning or Middle	# Marine Genera at End
Devonian	419.2	358.9	1559 (middle Devonian)	793
Carboniferous	358.9	298.9	833	1105

7. How long was the Devonian Period?
8. What percent of genera was lost during the Devonian Period?
9. What percentage of genera was gained during the Carboniferous Period?
10. Did the number of genera recover by the end of the Carboniferous?

Name: _____

Date: _____

End Permian Extinction

Directions: Use the Earth View web application by HHMI Biointeractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources including the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-permian-extinction/>) and PBS (<https://www.pbs.org/wgbh/evolution/change/deeptime/permian.html>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Permian Period
2. Compare what the planet looked like at the beginning of the Permian and the end. Do you notice any major changes? What do you see?
3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Permian?
4. How long was a day during the Permian Period?

Name: _____

Date: _____

5. What caused the extinction event at the end of the Permian Period?

6. What types of animals went extinct at the end of the Permian? Which ones survived?

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Devonian Period and the Carboniferous Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at beginning	# Genera at End
Permian	298.9	251.9	1098	293
Triassic	251.9	201.3	293	520

7. How long was the Permian Period?

8. What percent of genera was lost during the Permian Period?

9. What percentage of genera was gained during the Triassic Period?

10. Did the number of genera recover by the end of the Triassic?

Name: _____

Date: _____

End Triassic Extinction

Directions: Use the Earth Viewer web application by HHMI Biointeractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-triassic-extinction/>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Triassic Period
2. Compare what the planet looked like at the beginning of the Triassic and the end. Do you notice any major changes? What do you see?
3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Triassic?
4. How long was a day during the Triassic Period?

Name: _____

Date: _____

5. What caused the extinction event at the end of the Triassic Period?
6. What types of animals went extinct at the end of the Triassic? Which ones survived?

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Triassic Period and the Jurassic Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning or Middle	# Marine Genera at End
Triassic	251.9	201.3	762 (middle Triassic)	520
Jurassic	201.3	145.0	620	1275

7. How long was the Triassic Period?
8. What percent of genera was lost during the Triassic Period?
9. What percentage of genera was gained during the Jurassic Period?
10. Did the number of genera recover by the end of the Jurassic?

Name: _____

Date: _____

End Cretaceous Extinction

Directions: Use the Earth Viewer web application by HHMI Biointeractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources such as the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-cretaceous-extinction/>) and the American Museum of Natural History (<https://www.amnh.org/exhibitions/dinosaurs-ancient-fossils-new-discoveries/extinction/dinosaurs-survive>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Cretaceous Period
2. Compare what the planet looked like at the beginning of the Cretaceous and the end. Do you notice any major changes? What do you see?
3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Cretaceous Period?
4. How long was a day during the Cretaceous Period?

Name: _____

Date: _____

5. What types of plants and animals lived during that time?

6. What types of animals went extinct at the end of the Cretaceous? Which ones survived?

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Cretaceous Period and the Paleogene Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning	# Marine Genera at End
Cretaceous	145.0	66.0	1259	2209
Paleogene	66.0	23.03	1401	2219

7. How long was the Cretaceous Period?

8. What percent of genera was lost after the Cretaceous Period?

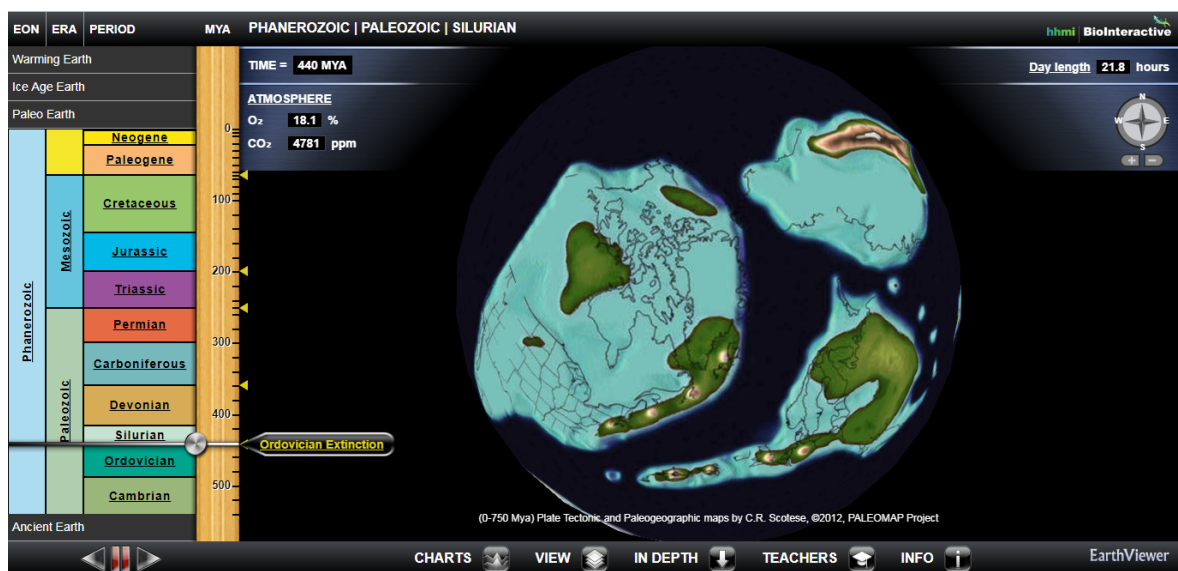
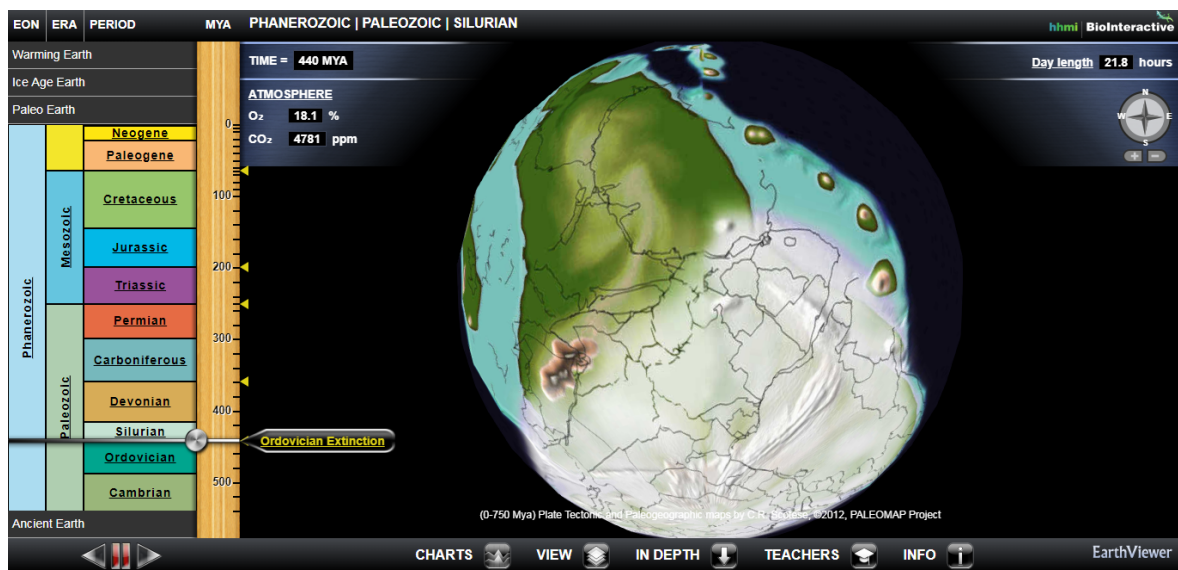
9. What percentage of genera was gained during the Paleogene Period?

10. Did the number of genera recover by the end of the Paleogene?

End Ordovician Extinction

Directions: Use the Earth View web application by HHMI BioInteractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-ordovician-extinction/>) to answer the following questions.

- Using Earth Viewer, draw a picture of what the planet looked like at the end of the Ordovician Period



Name: _____

Date: _____

2. Compare what the planet looked like at the beginning of the Ordovician and the end.

Do you notice any major changes? What do you see?

Large glaciers form at the end of the Ordovician

3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Ordovician?

Beginning: O₂ = 16.8%; CO₂ = 4903 ppm

End: O₂ = 17.9%; CO₂ = 4852 ppm

(There will be some slight variation depending on where students place the slider on the left-hand side of the screen)

4. How long was a day during the Ordovician Period?

21.6 -21.8 hours

5. What caused the extinction event at the end of the Ordovician Period?

The evidence indicates that climate change caused the extinctions. A major ice age is known to have occurred in the southern hemisphere and climates cooled world-wide.

The first wave of extinctions happened as the climate became colder and a second pulse occurred as climates warmed at the end of the ice age.

6. What types of animals went extinct at the end of the Ordovician? Which ones survived?

All of the major animal groups of the Ordovician oceans survived, including trilobites, brachiopods, corals, crinoids and graptolites, but each lost important members.

Widespread families of trilobites disappeared, and graptolites came close to total extinction.

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Ordovician Period and the Silurian Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning	# Marine Genera at End
Ordovician	488.3	443.7	284	1358
Silurian	443.7	416.0	838	1261

Name: _____

Date: _____

7. How long was the Ordovician Period?

488.7 million years – 443.7 million years = 55 million years

8. What percent of genera was lost from the end of the Ordovician to the beginning of the Silurian Period?

$1538 - 838 = 700$

$700 / 1538 = 0.455$ or **45.5%**

9. What percentage of genera was gained during the Silurian Period?

$1261 - 838 = 423$

$423 / 838 = 0.504$ or **50.4%**

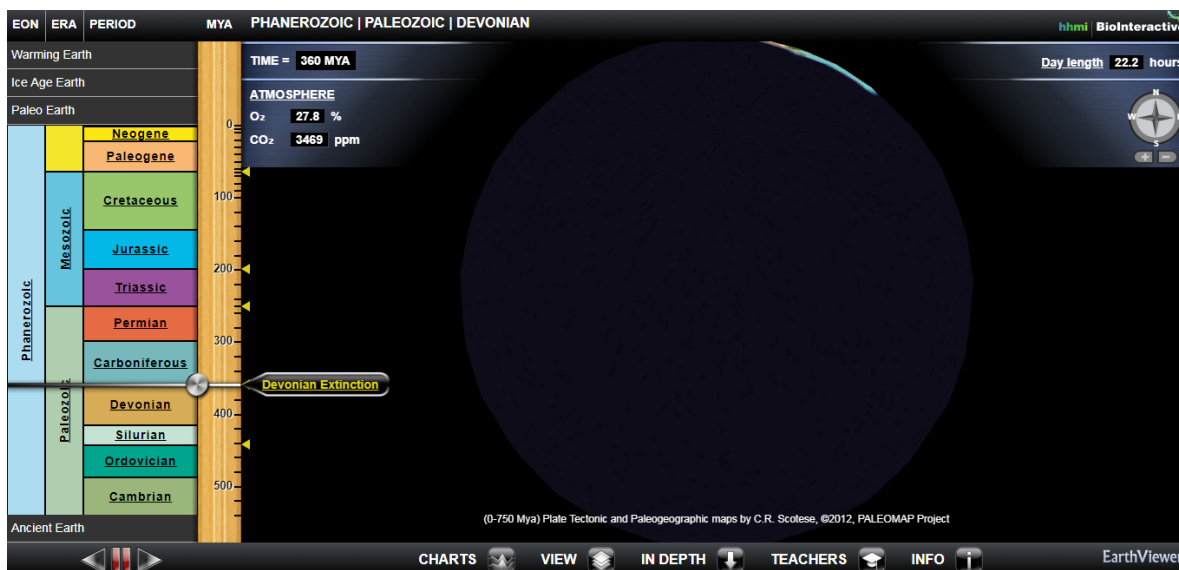
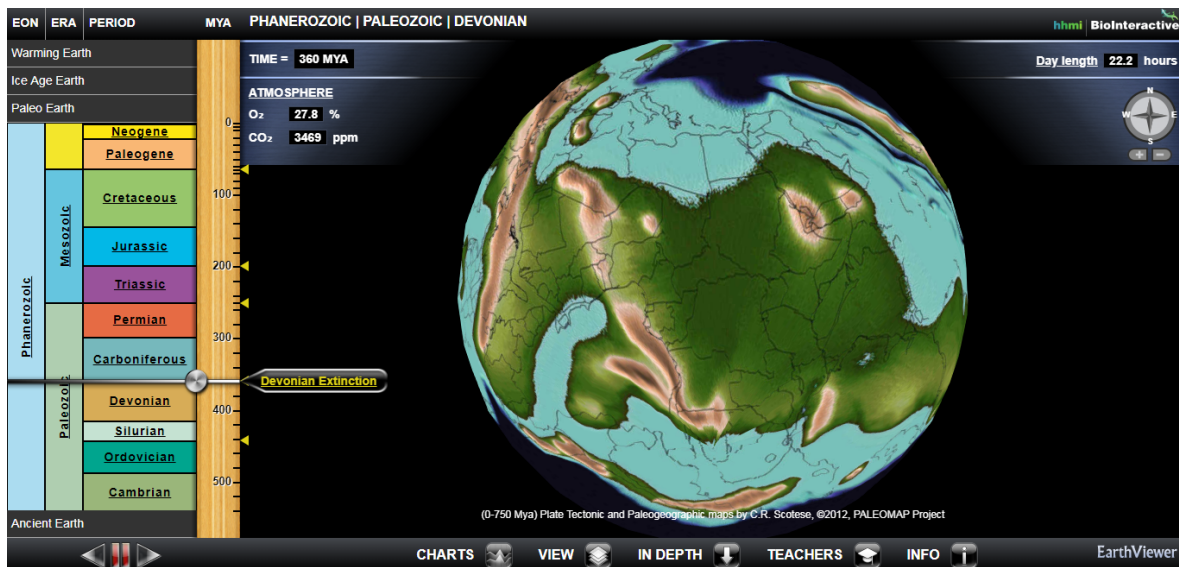
10. Did the number of genera recover by the end of the Silurian?

No

End Devonian Extinction

Directions: Use the Earth Viewer web application by HHMI BioInteractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources including the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/late-devonian-extinctions/>) or PBS (<https://www.pbs.org/wgbh/evolution/change/deeptime/devonian.html>) to answer the following questions.

- Using Earth Viewer, draw a picture of what the planet looked like at the end of the Devonian Period



Name: _____

Date: _____

2. Compare what the planet looked like at the beginning of the Devonian and the end.
Do you notice any major changes? What do you see?

A larger landmass is formed

More deserts on land by the end of the Devonian

3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Devonian?

Beginning: O₂ = 20.3% CO₂ = 4082 ppm

End: O₂ = 27.6 % CO₂ = 3474 ppm

(There will be some slight variation depending on where students place the slider on the left-hand side of the screen)

4. How long was a day during the Devonian Period?

21.9 -22.2 hours

5. What caused the extinction event at the end of the Devonian Period?

As extinctions were mostly of tropical groups climate change may have been involved, and there is geological evidence for cooling of the global climate at the end-Frasnian event and near the end of the Devonian Period.

Cooling may have been caused by a drop in the amount of carbon dioxide in the atmosphere. Carbon dioxide is a greenhouse gas that helps warm the planet, so if levels fall, cooling will follow. In the Late Devonian, large trees evolved and formed the first forests. As plant life expanded, they used up more carbon dioxide in photosynthesis. When dead plant material decays, carbon dioxide is returned to the atmosphere, but some plant material (e.g., leaves) will be buried in swamps, lakes and rivers. This buried plant material removes carbon permanently from the atmosphere and often forms coal. When we mine coal and burn it we return carbon dioxide to the atmosphere and warm the planet.

6. What types of animals went extinct at the end of the Devonian? Which ones survived?

The extinction was most pronounced in tropical environments, particularly in the reefs of the shallow seas. Reef building sponges called stromatoporoids and corals suffered losses and stromatoporoids finally disappeared in the third extinction near the end of the Devonian. Brachiopods associated with reefs also became extinct. Groups of trilobites disappeared at each of the three extinctions and very few survived into the following Carboniferous Period.

Name: _____

Date: _____

As for the marine vertebrates, the enigmatic conodont animals, known only for their widely scattered toothlike fossils, suffer; the jawless fishes are almost entirely eliminated; and the jawed and heavily armored placoderms go completely extinct. Interestingly, terrestrial plants and animals escape largely untouched.

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Devonian Period and the Carboniferous Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning or Middle	# Marine Genera at End
Devonian			1559	793
	419.2	358.9	(middle Devonian)	
Carboniferous	358.9	298.9	833	1105

7. How long was the Devonian Period?

419.2 million years – 358.9 million years = **60.3 million years**

8. What percent of genera was lost during the Devonian Period?

1559-793 = 766

766/1559 = 0.491 or **49.1%**

9. What percentage of genera was gained during the Carboniferous Period?

1105-833 = 272

272/833 = 0.327 or **32.7%**

10. Did the number of genera recover by the end of the Carboniferous? **No**

End Permian Extinction

Directions: Use the Earth View web application by HHMI BioInteractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources including the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-permian-extinction/>) and PBS (<https://www.pbs.org/wgbh/evolution/change/deeptime/perman.html>) to answer the following questions.

- Using Earth Viewer, draw a picture of what the planet looked like at the end of the Permian Period



Name: _____

Date: _____

2. Compare what the planet looked like at the beginning of the Permian and the end. Do you notice any major changes? What do you see?

At the beginning of the Permian, there were glaciers

By the end of the Permian, the glaciers were gone, and the landmasses came together and formed one large continent (Pangea)

3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Permian?

Beginning: O₂ = 33.1%; CO₂ = 323 ppm

End: O₂ = 26.3%; CO₂ = 574 ppm

(There will be some slight variation depending on where students place the slider on the left-hand side of the screen)

4. How long was a day during the Permian Period?

22.5 - 22.7 hours

5. What caused the extinction event at the end of the Permian Period?

Warming of the Earth's climate and associated changes to oceans were the most likely causes of the extinctions. At the end of the Permian Period volcanic activity on a massive scale in what is now Siberia led to a huge outpouring of lava. The eruptions also produced carbon dioxide, a greenhouse gas that helps warm the planet. The lava flows erupted onto carbon rich rocks like coal and as they were heated by the hot lava, greenhouse gases, including methane, were also produced. The global warming that followed may have increased average ocean water temperatures by as much as 14.5° F (8°C).

Much of the carbon dioxide released by the eruptions would have been absorbed by the oceans. High levels of dissolved carbon dioxide in seawater are toxic to many marine invertebrates. Also, the dissolved carbon dioxide would have produced changes in seawater chemistry that may have made it difficult for some marine invertebrates, such as corals, to grow shells or skeletons. If that wasn't bad enough, there is also geological evidence that the amount of oxygen dissolved in sea water (which invertebrates and fishes breathe with their gills) was reduced, probably as a result of changes in ocean circulation.

6. What types of animals went extinct at the end of the Permian? Which ones survived?

Important groups of marine animals disappeared at the end-Permian extinctions.

Trilobites, which had lived in the oceans for more than 250 million years, were lost, along with tabulate and rugose corals. Reef building in shallow seas stopped for about 14 million years until the middle of the following Triassic Period. At that time, an entirely

Name: _____

Date: _____

new group of corals, the stony or scleractinian corals, appeared in the oceans. Although they did not become entirely extinct, rhynchonelliform brachiopods, crinoids, shelled cephalopods and snails also suffered significant losses. On land, primitive synapsids (relatives of mammals) disappeared. Some estimates suggest that up to 70 percent of vertebrate genera were lost.

Marine predators such as sharks and coelacanths are hit hard, and coral reefs will require at least 10 million years to recover. Among the land animals, two-thirds of amphibian families, all large herbivores, and most reptiles die out. Terrestrial plants also suffer greatly.

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Devonian Period and the Carboniferous Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at beginning	# Genera at End
Permian	298.9	251.9	1098	293
Triassic	251.9	201.3	293	520

7. How long was the Permian Period?

298.9 million years – 251.9 million years = 47 million years

8. What percent of genera was lost during the Permian Period?

$1098 - 293 = 805$

$805/1098 = 0.733$ or **73.3%**

9. What percentage of genera was gained during the Triassic Period?

$520 - 293 = 227$

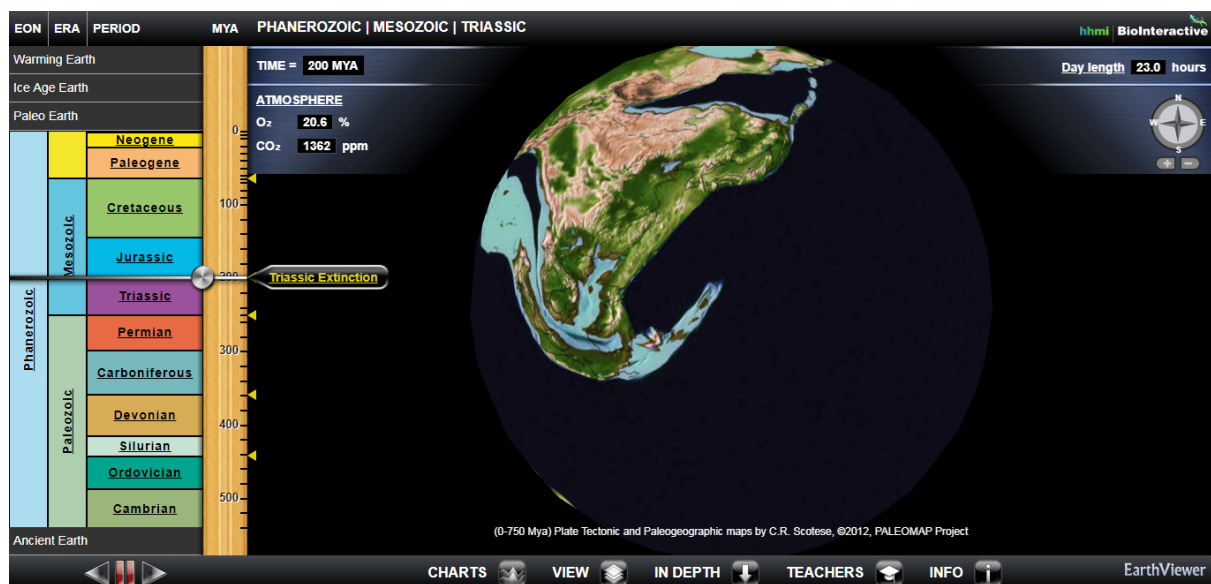
$227/293 = 0.775$ or **77.5%**

10. Did the number of genera recover by the end of the Triassic? **No**

End Triassic Extinction

Directions: Use the Earth Viewer web application by HHMI BioInteractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-triassic-extinction/>) to answer the following questions.

- Using Earth Viewer, draw a picture of what the planet looked like at the end of the Triassic Period



Name: _____

Date: _____

2. Compare what the planet looked like at the beginning of the Triassic and the end. Do you notice any major changes? What do you see?

The large landmass begins to separate by the end of the Triassic

3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Triassic?

Beginning: O₂ = 26.1%; CO₂ = 578 ppm

End: O₂ = 20.6%; CO₂ = 1362 ppm

(There will be some slight variation depending on where students place the slider on the left-hand side of the screen)

4. How long was a day during the Triassic Period?

22.8 – 23.0 hours

5. What caused the extinction event at the end of the Triassic Period?

At the end of the Triassic, the supercontinent of Pangea, which combined all of the modern continents into a single landmass, began to break (rift) apart. As North America separated from Africa and the Atlantic Ocean began to form, volcanic activity on a massive scale introduced carbon dioxide into the atmosphere. This led to global warming and changes to the oceans that were similar to (although not as large) those that occurred at the end-Permian extinction.

6. What types of animals went extinct at the end of the Triassic? Which ones survived? All major groups of marine invertebrates survived the extinction, although most suffered losses. Brachiopods, shelled cephalopods, sponges and corals were particularly hard hit. On land, casualties included the phytosaurs, a group of crocodile-like animals.

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Triassic Period and the Jurassic Period. Use this chart to answer the following questions.

Name: _____

Date: _____

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning or Middle	# Marine Genera at End
Triassic	251.9	201.3	762 (middle Triassic)	520
Jurassic	201.3	145.0	620	1275

7. How long was the Triassic Period?

$251.9 \text{ million years} - 201.3 \text{ million years} = 50.6 \text{ million years}$

8. What percent of genera was lost during the Triassic Period?

$762 - 520 = 242$

$242/762 = 0.3176$ or **31.8%**

9. What percentage of genera was gained during the Jurassic Period?

$1275 - 620 = 655$

$655/620 = 1.056$ = **105.6%**

10. Did the number of genera recover by the end of the Jurassic? **Yes**

End Cretaceous Extinction

Directions: Use the Earth Viewer web application by HHMI BioInteractive (http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html) and resources such as the Sam Noble Museum (<https://samnoblemuseum.ou.edu/understanding-extinction/mass-extinctions/end-cretaceous-extinction/>) and the American Museum of Natural History (<https://www.amnh.org/exhibitions/dinosaurs-ancient-fossils-new-discoveries/extinction/dinosaurs-survive>) to answer the following questions.

1. Using Earth Viewer, draw a picture of what the planet looked like at the end of the Cretaceous Period



Name: _____

Date: _____

2. Compare what the planet looked like at the beginning of the Cretaceous and the end. Do you notice any major changes? What do you see?

Africa and South America were still connected at the beginning of the Cretaceous, and they separated by the end.

There was more water covering the land at the beginning of the Cretaceous than the end.

3. What were the oxygen (O₂) and carbon dioxide (CO₂) levels in the atmosphere at the beginning and at end of the Cretaceous Period?

Beginning: O₂ = 20.7%; CO₂ = 1271 ppm

End: O₂ = 22.7%; CO₂ = 880 ppm

(There will be some slight variation depending on where students place the slider on the left-hand side of the screen)

4. How long was a day during the Cretaceous Period?

23.3 – 23.7 hours

5. What caused the extinction event at the end of the Cretaceous Period?

Several lines of geological evidence indicate that an asteroid that was as much as 10 kilometers (6 miles) in diameter hit the Earth at the end of the Cretaceous Period. This evidence includes an ancient impact crater in the Yucatan Peninsula of Mexico (now filled in by younger rocks) that dates to the time of the extinction. The impact would have produced an enormous dust cloud that would have risen up into the atmosphere and encircled the planet. The dust cloud greatly reduced the amount of sunlight reaching the Earth's surface and prevented photosynthesis by plants on land and plankton in the oceans. As plants and plankton died, extinctions expanded up the food chain, eliminating herbivores and carnivores. If that was not bad enough, dust and debris falling back to Earth was hot and may have triggered widespread wildfires. There is some debate over whether the asteroid was the sole cause of the extinction or whether other factors were also involved. Towards the end of the Cretaceous, volcanic activity in India produced lava flows over a vast area. Some paleontologists and geologists have suggested that gases (e.g., sulfur dioxide; carbon dioxide) released by the volcanoes might have altered the climate. Others point to geological evidence for a fall in sea level that would have reduced the area of shallow seas and, possibly, coastal plains.

Name: _____

Date: _____

6. What types of animals went extinct at the end of the Cretaceous? Which ones survived?

In addition to the non-avian dinosaurs, vertebrates that were lost at the end of the Cretaceous include the flying pterosaurs, and the mosasaurs, plesiosaurs and ichthyosaurs of the oceans. Important marine invertebrates also disappeared, including ammonites, groups of cephalopods and some bivalves, such as the reef-building rudists and some relatives of modern oysters.

Survivors include:

- Alligators & Crocodiles
- Birds: Birds are the only dinosaurs to survive the mass extinction event 65 million years ago.
- Frogs & Salamanders
- Lizards
- Mammals
- Snakes
- Turtles: Of the known species of turtles alive at the time of the dinosaurs, more than 80 percent survived.

Below is a chart showing the number of marine (living in the ocean) genera (groups of species that are more related to each other than to other species) that lived during the Cretaceous Period and the Paleogene Period. Use this chart to answer the following questions.

	Begin (Ma)	End (Ma)	# of Marine Genera at Beginning	# Marine Genera at End
Cretaceous	145.0	66.0	1259	2209
Paleogene	66.0	23.03	1401	2219

7. How long was the Cretaceous Period?

145 million years – 66 million years = 79 million years

8. What percent of genera was lost after the Cretaceous Period?

$2209 - 1401 = 808$
 $808/2209 = 0.366$ or **36.6%**

Name: _____

Date: _____

9. What percentage of genera was gained during the Paleogene

Period? $2219 - 1401 = 818$

$818/1401 = 0.584$ or **58.4%**

10. Did the number of genera recover by the end of the Paleogene? **Yes**