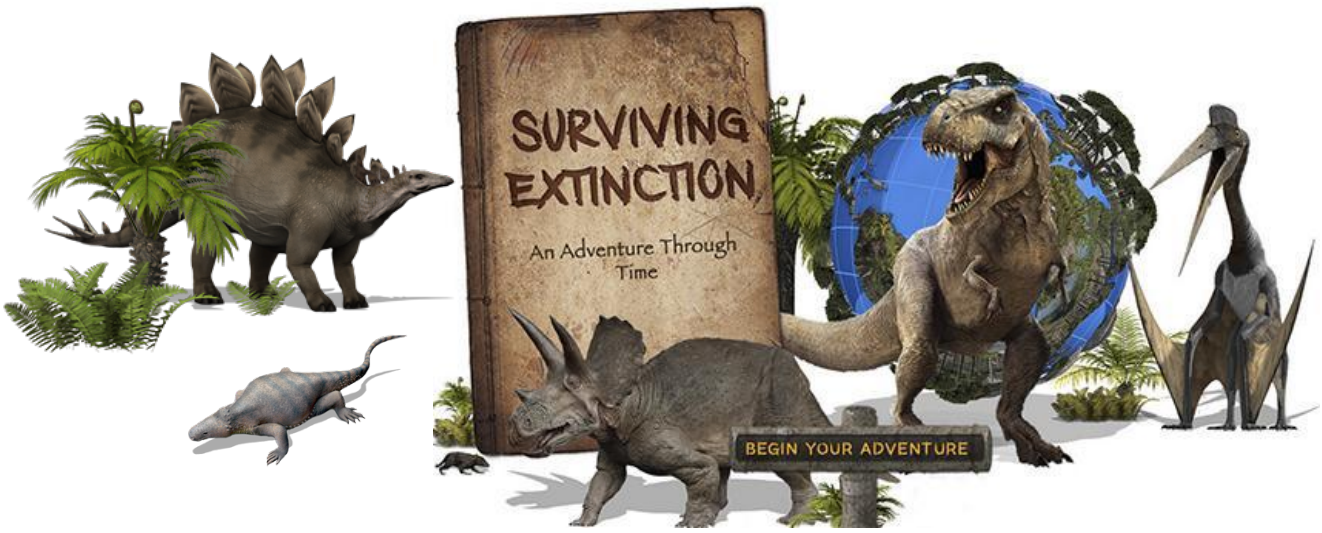


Mass Extinction Lesson Description

Explore how your vertebrate ancestors survived three mass extinctions and gave rise to the great variety of groups alive on Earth today. Learn what adaptations helped make some groups more successful than others. Test your ability to predict which physical, behavioral and physiological traits were instrumental in helping some groups cope with environmental changes. Find out how to survive extinction!

Central Question: How have environmental changes during mass extinctions caused some vertebrates and their ancestors to go extinct?

Instructional Objective: Evaluate how changes in environmental conditions during mass extinctions may result in the appearance of new species and the extinction of other species over time.

Learning Outcomes

Learning Outcome #1: Explain the advantages and disadvantages of specific adaptive traits for species survival.
Learning Outcome #2: Evaluate and categorize key mammalian and reptilian adaptive traits.
Learning Outcome #3: Describe environmental changes and how they led to mass extinctions.

Prerequisites

- Traits (anatomical or structural, behavioral, physiological)
- Extinction
- Geologic time
- Ecosystem

Surviving Mass Extinctions

Grades: 10-12 Prep time: ~15 min Lesson time: 5 days

WHAT LEARNERS DO: Play the online game *Surviving Extinction*.

Through playing *Surviving Extinction,* learners follow vertebrate evolution through the last 350 million years to discover how mass extinctions affected the evolution of mammals, reptiles and their ancestors.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS

HOW DID ENVIRONMENTAL CHANGES DURING MASS EXTINCTIONS AFFECT THE SURVIVAL OF VERTEBRATE GROUPS OVER TIME?

NGSS Core Question: HS.Natural Selection and Evolution, Adaptation

What is the evidence for the effects of environmental changes on the survival of mammals, reptiles and birds over the past 350 million years?

What were the causes of mass extinctions during the Mesozoic Era?

NGSS DISCIPLINARY CORE IDEAS

HS-LS4-5

Students who demonstrate understanding can:

HS-LS4-5. **Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.** [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

Science and Engineering Practices

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science.

- Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.

Disciplinary Core Ideas

LS4.C: Adaptation

- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

INSTRUCTIONAL OBJECTIVE (IO)

Learners will be able to

IO1: Evaluate how changes in environmental conditions during mass extinctions may result in the appearance of new species and the extinction of other species over time.

1.0 Materials

Required Materials:

Please Supply:

- Computer or Laptop - 1 per learner
    - Supported Browsers: Chrome or Firefox
- Headphones or earbuds - 1 per learner

Please Print:

From Learner Guide

(A) Anthropocene Recording Sheet - 1 per learner
(B) Mass Extinction (Mammals) Recording Sheet - 1 per learner
(C) Mass Extinction (Dinosaurs/Birds) Recording Sheet - 1 per learner
(D) Mass Extinction Causes and Ranking Recording Sheet - 1 per learner
(E) Surviving Extinction Tally Sheet (Optional) - 1 per learner
(F) Mass Extinction Survey - 2 per learner

Optional Materials:

EarthViewer
https://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html

The Day the Mesozoic Died; video and lesson materials
https://www.biointeractive.org/classroom-resources/day-mesozoic-died

Understanding Evolution 101
https://evolution.berkeley.edu/evolibrary/article/evo_01
Understanding Evolution Misconceptions
https://evolution.berkeley.edu/evolibrary/misconceptions_faq.php

2.0 Lesson Timeline

Mass Extinction Lesson Timeline:

Time:

- 5 days

Materials:

- Laptop computer
- Internet connection
- Student Guide pages

5-E Inquiry Process:

- The arrow color represents the 5-E step students will be primarily engaged in for that class session

Day 1 (30-40 min)

Engage
- (F) Mass Extinction Survey
- Watch video
- (A) Anthropocene Recording Sheet

Day 2-3 (~30-90 min)

Explore
- Gameplay mammal line
- Gameplay bird line
- (B-C) Recording Sheets

Day 2-3 (~20-30 min)

Explain
- Develop lists of extinct mammals and dinosaurs/birds
- (B-C) Recording Sheets

Day 4 (~30-40 min)

Elaborate
- Mass Extinction interactive
- The Big Five Discussion
- (D) Mass Extinction Causes and Ranking

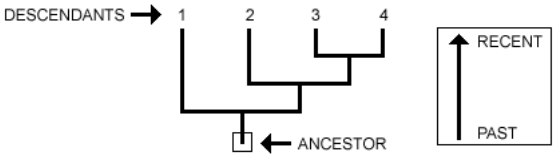
Day 5 (~20 min)

Evaluate
- (E) Surviving Extinction Tally Sheet
- (F) Mass Extinction Survey

3.0 Vocabulary

adaptive trait feature that has evolved by natural selection for a specific function that helps an organism survive in its environment; also known as an adaptation

ancestor earlier organisms or groups from which later kinds evolved



asteroid small, rocky objects that orbit the Sun; most are found in the asteroid belt between Mars and Jupiter

ecosystem biological community of interacting organisms and their physical environment

evolution the process in which populations of organisms over time inherit changes in physical, behavioral or physiological traits that allow an organism to better survive in its environment and have more offspring

extinction event in which the last members of a lineage or species die

flood basalt volcanic eruptions characterized by enormous and prolonged out-pouring of lava from extensive cracks in the ground or fissures

food web interconnection of food chains as a graphical representation of what-eats-what in an ecological community

habitat place and conditions in which an organism normally lives

lineage continuous line of descent from ancestor to descendant over time; a series of organisms or populations connected by ancestor/descendant relationships

mass extinction event in which many lineages go extinct around the same time; involving higher rates of extinction than the usual rate of background extinction that is going on all the time

4.0 Procedure

PREPARATION

A. Each learner needs access to a laptop or desktop computer and headphones or earbuds (for listening to videos and sound effects).

B. Test the internet connection of the *Surviving Extinction* online game (https://vft.asu.edu/survive/) by logging into computers with student credentials using the browsers Google Chrome or Firefox. Note: the game is not optimized for Safari or mobile devices.

C. Start the game and review the instructions in the **Survival Guide Table of Contents.** Here learners will find the **Pre-Adventure** and **Begin Adventure** details. It is important to review these sections to be familiar with the game tasks, icons, tokens and gear before starting the lesson with learners.

The goal of the game is to complete five main tasks; the most important task is to build an evolutionary tree from your tetrapod ancestor to a chosen modern-day animal. Learners choose to take on the role of different animals and visually explore the environmental and biological changes that occurred from 350 million-years-ago to the present. They must decide which group of animals to follow as their traits change in relation to environmental pressures, ecological niche changes, new species interactions, and key mass extinctions.

D. PRINT THE FOLLOWING:

• Learner **Recording Sheets (A-F)** –1 per learner

STEP 1: ENGAGE (~30-40 minutes)

Day 1: Human Impacts

A. Hand out the **(F) Surviving Extinction Survey** and have learners answer the questions before they start the lesson.

Option 1:

1. Have learners open the following HHMI interactive on their computer:
The Anthropocene: https://media.hhmi.org/biointeractive/click/anthropocene/

2. Prior to starting the digital lesson with the *Surviving Extinction* game, hand out **(A) Anthropocene Recording Sheet** and have learners play through the interactive. Ask learners to list the different ways humans are having an impact on the Earth.

3. After finishing the sheet, engage the learners: ask them which human activities do they think are having the biggest impact on Earth today? Are there factors that are not addressed in the interactive (e.g., human population growth, depletion of resources) that are major drivers of these environmental changes? Did extinction of species in the past play a major role in the evolution of life? This is what they will explore in more detail by playing the *Surviving Extinction* game.

Option 2:

1. Have learners watch the first minute of the video (1 min): The Day the Mesozoic Died: https://youtu.be/tRPu5u_Pizk

2. After finishing the sheet, engage the learners: ask them if they know what caused the extinction of the dinosaurs? Did any dinosaurs survive this mass extinction event? Were there other mass extinctions that took place on Earth in the past? This is what they can explore by playing the *Surviving Extinction* game.

B. During this experience, learners will demonstrate their prior knowledge of mass extinctions and their possible causes, including the activities of humankind.

STEP 2: EXPLORE (~30-90 minutes, 2 days)

Day 2: Playing *Surviving Extinction* - Mammals

A. Begin the digital lesson, hand out **(B) Mass Extinction (Mammals) Recording Sheet** and computers and headphones. Ask learners to go to https://vft.asu.edu/survive/.

B. Instruct learners to launch the game and watch the introductory video. Have them take time to look through the **Pre-Adventure instructions** and go over the gear and survival tips.

C. To begin the game, have them **Select a Descendant** from among the *mammal (living) destination animals* choosing one of the difficult or hardest level mammals such as the lion, human, chimpanzee or whale.

D. Learners should play through from the early tetrapod ancestor at the base of the evolutionary tree all the way through to their chosen destination animal. This completes one pathway on the evolutionary tree.

E. As they work, have learners use the **(B) Mass Extinction (Mammals) Recording Sheet** to list each ***Extinction Animal*** that they encountered along the mammal pathway and fill in the name, geologic age, environmental changes that were occurring during the time, and current theory for that animal group's extinction. They should also note any adaptations other groups had that helped them become a dominant group after the extinction event. Each *Extinction Animal* window contains the information they need for the table.

Day 3: Playing *Surviving Extinction* - Birds

A. Have learners launch the game again, but this time have them choose one of the *bird (living) destination animals* (eagle or penguin) and play through this pathway.

D. As they work, have learners use the **(C) Mass Extinction (Dinosaurs/Birds) Recording Sheet** to list each ***Extinction Animal*** that they encounter along the mammal pathway and fill in the name, geologic age, environmental changes that were occurring during the time, and current theory for that animal group's extinction. They should also note any adaptations other groups had that helped them become a dominant group after the extinction event. Each *Extinction Animal* window contains the information they need for the table.

C. Encourage learners to play through as many additional game pathways as they want (this can be done from home) and record the results of their tasks in the **(E) Surviving Extinction Tally Sheet**. Note: It can take anywhere from three to four hours (or more) to complete the entire game.

 Teacher Tip: If learners get stuck or have Internet issues, they can restart the game and *Return to your current adventure*, to get back to where they left off.

 Teacher Tip: Instruct learners on how to take a screenshot with their computer to capture any scores on the key challenges or their main score, if desired.

 Teacher Tip: Learners should never hit the browser's "Refresh" or "Back" button.

 Teacher Tip: Learners are expected to learn from their failures. This failure model is commonly found in the fields of science and engineering. Failure should not be viewed as a value judgement, but as an example of a *First Attempt in Learning*. It's an example of what doesn't work, and learners should keep exploring to find what does work.

STEP 3: EXPLAIN (~20-30 minutes)
Day 2: Exploring mass extinctions - causes

A. After learners have played through one mammal and one bird pathway, hand out **(D) Mass Extinction Causes and Ranking Recording Sheet** and have them open *The Making of Mass Extinctions* interactive. Have them list three main causes of mass extinction events and rank them in terms of the percent of species that died out.

1. Have learners open up The Making of Mass Extinctions HHMI interactive: https://media.hhmi.org/biointeractive/click/extinctions/

2. Based on the interactive and the information collected by learners on their **(B) Mass Extinction (Mammals) Recording Sheet**, have them work individually or as a group to list four main causes of mass extinctions that affected the mammals. Have them enter this information in the **(D) Mass Extinction Causes and Ranking Recording Sheet** (Part A)

Day 3: Exploring mass extinctions - ranking

1. Have learners open up The Making of Mass Extinctions HHMI interactive: https://media.hhmi.org/biointeractive/click/extinctions/

2. Based on the interactive and the information collected by learners on their **(C) Mass Extinction (Dinosaurs/Birds) Recording Sheet,** have them work individually or as a group to rank the **Big Five** mass extinctions in order of the percentage of species wiped out. Have them enter this information in the **(D) Mass Extinction Causes and Ranking Recording Sheet** (Part B).

STEP 4: ELABORATE (~30-40 minutes)
Day 4: Extinctions past and present

Option 1

A. Spend the last session having learners elaborate on what they learned by reviewing the information that they collected in the **(D) Mass Extinction Causes and Ranking Recording Sheet** on Days 2-3. Have them expand on this by comparing the causes of mass extinctions in the past with the affects that humans are having on the Earth today.

B. Have learners refer to the **(A) Anthropocene Recording Sheet** information that they collected when they used The Anthropocene interactive on day one.

C. Ask learners if the *Surviving Extinction* game helped them understand more about the causes of mass extinctions and their effects on vertebrate evolution.

STEP 5: EVALUATE (~20 minutes)
Day 5: Evaluation of the game experience

A. Collect the **(E) Surviving Extinction Tally Sheet** (if this was used) where learners have recorded their game tasks and scores of the Key Challenges. This is especially useful if learners played through the entire game.

B. Hand out **(F) Mass Extinction Survey** for learners to complete. They will answer a series of questions and generate explanations of their understanding of the causes and significance of mass extinctions in mammal, reptile and bird evolution.

5.0 Evaluation / Assessment

The three Key Challenges (Bronze, Silver and Gold) are knowledge checks based on the game's learning objectives. Learners can either take a screenshot of their scores or use the *(E) Surviving Extinction Tally* Sheet to record their game progress and scores. Additionally, the *(F) Mass Extinction Survey* can be used to provide a formative and summative final assessment of the learning activities.

6.0 Extensions

A. Visit these sites for additional information and resources:

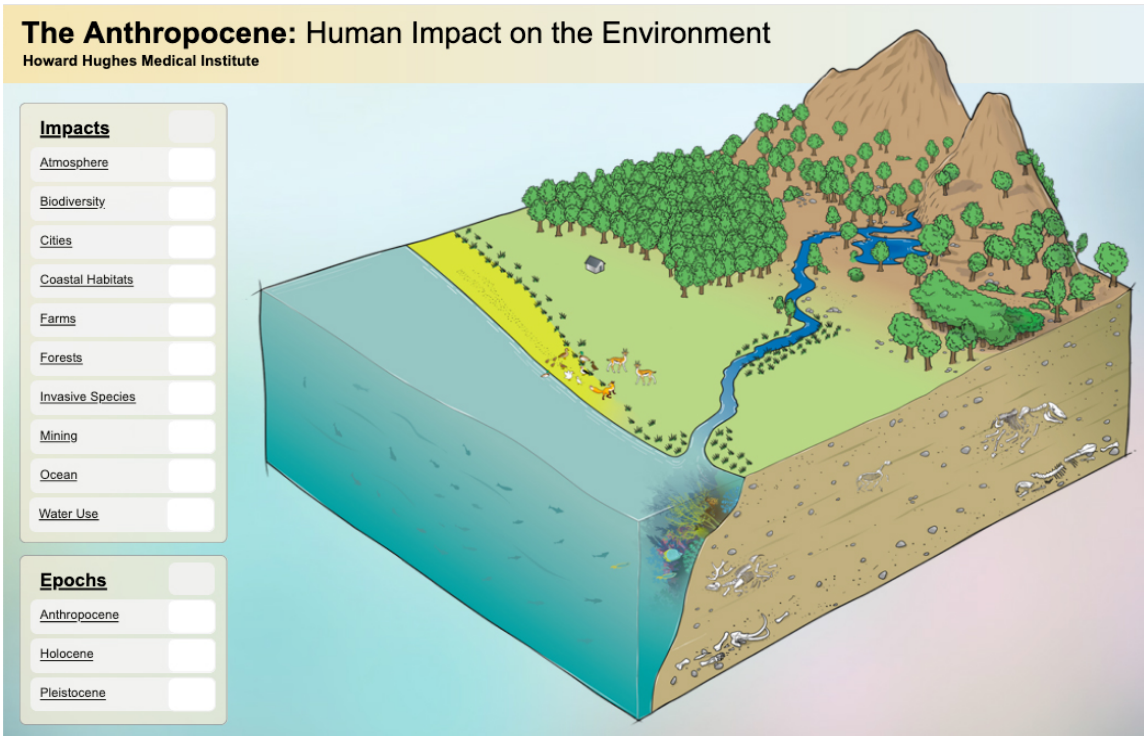
1. https://www.biointeractive.org/
2. https://evolution.berkeley.edu/evolibrary/home.php
3. https://humanorigins.si.edu/education/introduction-human-evolution
4. https://serc.carleton.edu/index.html

(A) Anthropocene *Recording Sheet*

Name: _____

Open up **The Anthropocene: Human Impact on the Environment** on your computer: https://media.hhmi.org/biointeractive/click/anthropocene/

1. Check off the impacts as you view them and then rank them in order according to what you think are the **three biggest impacts** on Earth today and **explain why** you feel this way. 1 = highest impact, 2 = lower impact, and 3 = lowest impact



	Impacts	Reason(s) behind your ranking?
1		
2		
3		

(B) Mass Extinction (Mammals) Recording Sheet

Name: _____

As you are following one of the **mammal pathways** in the *Surviving Extinction* game, record the age, name, environmental changes that were occurring during the time of the extinction, and the theory for the group's extinction for each *Extinction Animal* you encounter along the pathway. Also, pay attention to the animals that rose to dominance after the extinction event. If you miss the extinction animals, you can go back down your pathway and choose other animals to find them.

No.	**Time** (millions of years)	**Extinction Animal Name**	**Environmental changes during time of extinction**	**Theory for group's extinction**	**Name at least one other group that has survived and diversified**
1					
2					
3					
4					
5					
6					
7					

(C) Mass Extinction (Dinosaurs/Birds) Recording Sheet

Name: _____

As you are following one of the **bird pathways** in the *Surviving Extinction* game, record the age, name, environmental changes that were occurring during the time of the extinction, and the theory for the group's extinction for each *Extinction Animal* you encounter along the pathway. Also, pay attention to the animals that rose to dominance after the extinction event. If you miss the extinction animals, you can go back down your pathway and choose other animals to find them.

No.	**Time** (millions of years)	**Extinction Animal Name**	**Environmental changes during time of extinction**	**Theory for group's extinction**	**Name at least one other group that has survived and diversified**
1					
2					
3					
4					
5					
6					
7					
8					

(D) Mass Extinction Causes and Ranking

Name: _____

Part A. Based on the information that you recorded in ***(B) Mass Extinction (Mammals) Recording Sheet*** list and explain three causes of mass extinctions.

	Time (millions of years)	**Main cause or causes?**
1		
2		
3		
4		

Part B. Based on the information in *The Making of Mass Extinctions* interactive, rank the "Big Five" mass extinctions in terms of the percentage of species that died out. 1 = greatest % to 5 = lowest %

Rank	**% Species extinct**	**Mass extinction name**	**Time of mass extinction** (millions of years)	**What main groups went extinct?**
1				
2				
3				
4				
5				

(E) Surviving Extinction Tally Sheet (Optional)

Name: _____

Use this chart to record progress and totals from the Key Challenges and Hidden Real-World Locations within the *Surviving Extinction* game.

(F) Mass Extinction Survey

Name: _____

Complete the following:

1. Which of the following groups of animals went extinct 66 million years ago?
    a. Mammals
    b. Birds
    c. Reptiles
    d. Dinosaurs

2. What environmental changes led to the dinosaur's extinction 66 million years ago?
    a. Massive flooding and earthquakes
    b. Reversal of the Earth's magnetic field
    c. Asteroid impact and volcanic eruptions
    d. Gamma ray burst from space
    e. None of these

3. What does it mean when a group of animals goes extinct?
    a. Disappearance of a group from one area because it has moved away
    b. Appearance of a group in an area where it has never lived before
    c. Total disappearance of a group on Earth
    d. Disappearance of a group with reappearance of it later in time
    e. None of these

4. Which one of these mass extinctions was the largest that the Earth has ever experienced?
    a. Cretaceous-Paleogene (K-T or K-Pg) boundary 66 million years ago
    b. Permian-Triassic (P-T) boundary 252 million years ago
    c. Triassic-Jurassic (T-J) boundary 201 million years ago
    d. Cambrian-Ordovician (C-O) boundary 485 million years ago

5. Over the past 500 million years, life on Earth has experienced five main mass extinctions. Have you heard of the sixth extinction? If so, explain what could be causing this mass extinction.