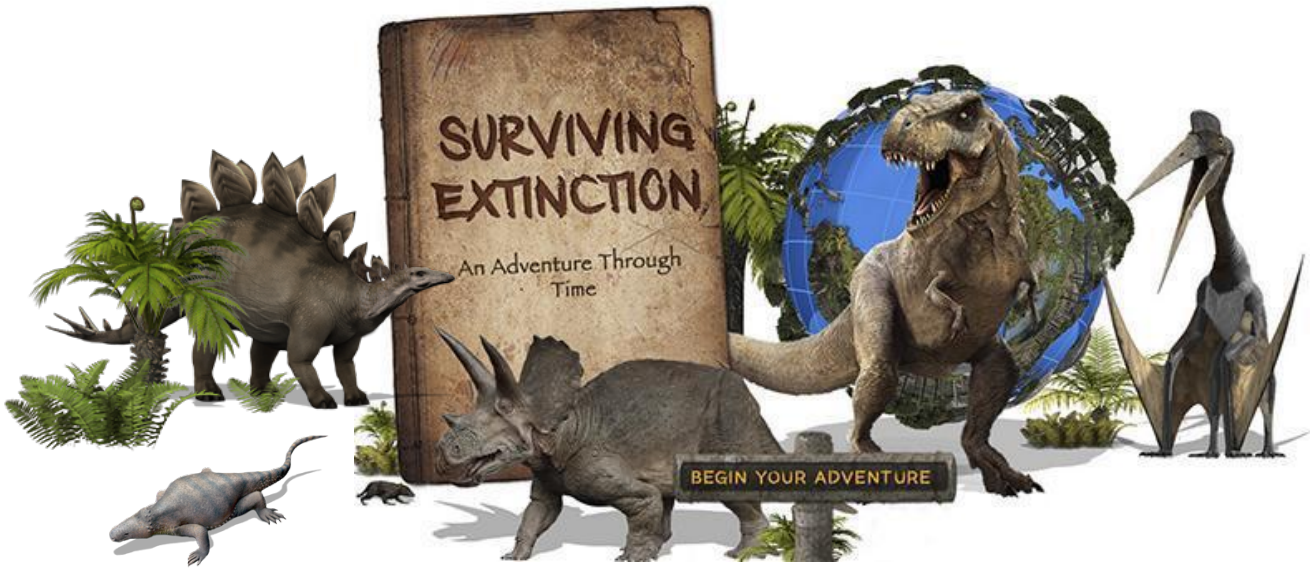


Natural Selection & Adaptation Lesson Description

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: Why have some animal groups survived environmental changes over time, while others have failed and gone extinct?

Instructional Objective: Explain how natural selection leads to the rise of beneficial traits and the extinction of organisms in a changing environment.

Learning Outcomes

Learning Outcome #1: Explain the benefits of specific anatomical (structural), behavioral or physiological adaptations or traits for species' survival.

Learning Outcome #2: Correlate certain animal's adaptive traits with the survival or extinction of its group in a mass extinction event.

Prerequisites

- Trait or adaptation
- Mass extinction
- Geologic time
- Ecosystem

Natural Selection & Adaptation

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 what adaptations helped mammals, reptiles and their ancestors survive mass extinctions.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS

WHAT ADAPTIVE TRAITS HELPED VERTEBRATE GROUPS SURVIVE MASS EXTINCTIONS?

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

What are the benefits of specific traits in the survival of mammals, reptiles and birds?

How have environmental changes during mass extinctions affected the survival of species over time?

HS.Natural Selection and Evolution; LS4.C Adaptation

NGSS DISCIPLINARY CORE IDEAS

HS.Natural Selection and Evolution

HS.Natural Selection and Evolution

Students who demonstrate understanding can:

HS-LS4-1. **Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.** [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

HS-LS4-2. **Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]

HS-LS4-3. **Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.** [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

HS-LS4-4. **Construct an explanation based on evidence for how natural selection leads to adaptation of populations.** [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

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 expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2),(HS-LS4-4)

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. (HS-LS4-5)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1)

Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-1)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)

LS4.C: Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4)
- Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3)
- 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. (HS-LS4-5)
- 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. (HS-LS4-5)

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1),(HS-LS4-3)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2),(HS-LS4-4),(HS-LS4-5)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-1),(HS-LS4-4)

INSTRUCTIONAL OBJECTIVE (IO)

Learners will be able to

IO1: Explain how natural selection leads to the rise of beneficial traits and extinction of organisms in a changing environment.

1.0 Materials

Required Materials:

Please Supply:

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

Please Print:

From Learner Guide

(A) Adaptation Observations Recording Sheet - 1 per learner
(B) Mammal Adaptation Recording Sheet - 1 per learner
(C) Bird Adaptation Recording Sheet - 1 per learner
(D) Construct an Explanation - 1 per learner
(E) Surviving Extinction Tally Sheet (Optional) - 1 per learner
(F) Surviving Extinction Survey - 2 per learner

Optional Materials:

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

Great Transitions Interactive: Exploring Transitional Fossils
https://media.hhmi.org/biointeractive/click/great-transitions/

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

Natural Selection & Adaptation 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) Surviving Extinction Survey
- Watch video
- (A) Adaptation Observations 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

- Watch videos
- List of traits using (B, C) Recording Sheets
- (D) Construct an explanation sheet

Day 4 (~30-40 min)

Elaborate

- Human traits discussion (or) Classification activity

Day 5 (~20 min)

Evaluate

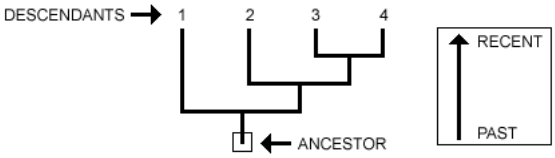
- (E) Surviving Extinction Tally Sheet
- (F) Surviving Extinction Survey

3.0 Vocabulary

adaptive trait feature (also known as an **adaptation**) that has evolved by natural selection for a specific function that helps an organism survive in its environment; adaptation can also be a process referring to the change in the distribution of traits within a population

anatomical trait (or structural trait) physical characteristics on an organism that help it survive in its natural habitat (e.g., lions have huge canine teeth and retractable claws to help them catch prey)

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

behavioral trait activities that an organism does to help it survive in its natural habitat (e.g., bears hibernate, or birds migrate in winter to escape the cold temperatures)

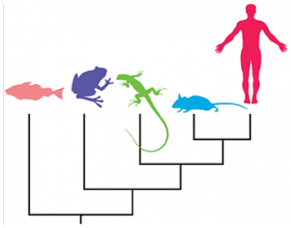
common ancestor ancestral organism shared by two or more descendant lineages - in other words, an ancestor that they have in common

descendant organism or group that is descended from a specific ancestor; an offspring

ecosystem biological community of interacting organisms and their physical environment

evolution descent with modification from preexisting species; process where 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

evolutionary tree known as a “family tree” or phylogenetic tree; a diagram that represents evolutionary relationships among organisms



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

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

natural selection a process whereby species which have advantageous traits that enable them to adapt to an environment, survive and reproduce, thereby passing on their genes to the next generation

niche an organism's environment as well as its role within that environment

physiological trait processes occurring inside an organism that enable it to survive in its natural habitat (e.g., snakes produce poisonous venom to ward off predators and capture prey)

species group of individuals that can interbreed to produce viable offspring in nature

trait specific characteristic of an organism; can be structural (physical characteristics), behavioral (how an animal behaves) or physiologic (how a body functions); also called adaptive trait or an adaptation

transitional forms fossils or organisms that show the intermediate states between an ancestral form and that of its descendants

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 (~45-60 minutes)

Day 1: Natural selection and animal adaptations

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

B. Introduce the concept of natural selection by having the students watch the video (10 min) Natural Selection and the Rock Pocket Mouse (https://youtu.be/sjeSEngKGrg)

C. After the video, ask students for their own definitions of natural selection, using guided questions such as, what is a random component to natural selection? What are some ways that natural selection can sort out “winners” and “losers”?

D. Have learners watch the video (17 min):
The Origin of Four-Legged Animals; https://youtu.be/zK8XGEDcTfo

E. Prior to starting the digital lesson with the *Surviving Extinction* game, hand out **(A) Adaptation Recording Sheet** (one page) and have learners pick a mammal, reptile or bird of their choice (or provide an image of an animal). Ask learners to make a sketch of that animal and record their observations of the types of traits or characteristics that animal possesses.

1. During this experience, learners will demonstrate their prior knowledge of the types of animal adaptations and their functions.

F. After finishing the sheet, engage the learners, ask them what they think their early vertebrate ancestors were like? Were these early ancestors very different from animals today? What were their environments like millions of years ago? This is what they can explore by playing the *Surviving Extinction* game.

STEP 2: EXPLORE (~30-90 minutes, 2 days)
Day 2: Playing *Surviving Extinction* - mammals

A. Begin the digital lesson, hand out **(B) Mammal Adaptations Recording Sheet, (C) Surviving Extinction Tally Sheet,** 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) Mammal Adaptations Recording Sheet** to list one key trait and its benefit for each main animal that they encounter along the mammal pathway. They can find the trait information in the *DNA icon* for each main animal.

Day 3: Playing *Surviving Extinction* - birds

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

D. As they work, learners should use the **(C) Bird Adaptations Recording Sheet** to list one key trait and its benefit for each main animal that they encounter along the bird pathway. They can find the trait information in *DNA icon* for each main animal.

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 select "*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; 2 days)

Day 2: Exploring mammal evolution

A. After learners have played through one mammal and one bird pathway, have them watch these two videos on the adaptations of each group and come up with a short list of the main mammal and bird adaptations or traits.

1. Have learners watch the video: (16 minutes): Out of the Ashes: Dawn of the Age of Mammals, https://youtu.be/IPlOLaY5xbA

2. Based on the video and the information collected by learners on their **(B) Mammal Adaptations Recording Sheet**, have them work individually or as

a group to come up with a list of the main mammal adaptations or traits and explain their choices.

Day 3: Exploring bird evolution

1. Have learners watch the video (19 minutes): The Origin of Birds, https://youtu.be/z4nuWLd2ivc

2. Based on the video and the information collected by learners on their **(C) Bird Adaptations Recording Sheet,** have them work individually or as a group to come up with a list of the main mammal adaptations or traits and explain their choices.

Have learners construct an explanation that identifies how natural selection leads to the rise of beneficial traits and extinction of organisms in a changing environment on the **(D) Construct an Explanation** sheet.

STEP 4: ELABORATE (~30-40 minutes)

Day 4: Human adaptations

Option 1

A. Spend the last session having learners elaborate on what they learned by making the trait lists for mammals and birds on Days 2-3. Have them expand on this by thinking about which of these traits we have inherited from our tetrapod ancestors that we possess as part of our body today.

B. Have learners open and go through: Explore your Inner Animals https://media.hhmi.org/biointeractive/click/explore-your-inner-animals/

C. Ask learners to describe where in the *Surviving Extinction* game they remember seeing these traits appear and if they can put them in a chronological order.

Option 2

A. Give learners a collection of animal models (fossil and modern) and have them organize the animals into groups based on their adaptations or traits. This could also be done with a collection of images.

B. Ask learners to describe the criteria they used for their classification using scientific concepts and vocabulary.

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 or the Key Challenges. This is especially useful if learners played through the entire game.

B. Hand out **(F) Surviving Extinction Survey** for learners to complete. They will answer a series of questions and generate explanations of their understanding of the broad trends and key events 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) Surviving 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) Adaptation Observations Recording Sheet

Name: _____

Watch the videos shown by the teacher and complete the following:

1. In your own words, describe natural selection.

2. Sketch a mammal, bird or reptile of your choosing in this space.

3. For your animal, list one adaptation or trait of each type and its possible function.

	Adaptation or trait	**What is it used for?**
Anatomical (structural) Adaptation *(physical feature an organism has that helps it survive in its natural habitat, such as huge fangs or wings)*		
Behavioral Adaptation *(activity that an organism does that helps it survive in its natural habitat, such as burrowing or herding)*		
Physiological Adaptation *(process occurring inside an organism that enables it to survive in its natural habitat; such as venom or warm-blooded metabolism)*		

(B) Mammal Adaptation Recording Sheet

Name: _____

As you are following one of the **mammal pathways** in the *Surviving Extinction* game, list one main adaptation or trait and its general benefit for eight main animals that appear in the environments that you explore. Describe how this key adaptation aided the animal's survival. *Hint: Look for the animals with a DNA icon to access this information.*

Main animal's name	**Age** (millions of years)	**Animal group**	**Key adaptation** (Hint: look for the DNA icon) 	**General benefit of adaptation on survival**

(C) Bird Adaptation Recording Sheet

Name: _____

As you are following one of the **bird pathways** in the *Surviving Extinction* game, list one main adaptation or trait and its general benefit for eight main animals that appear in the environments that you explore. Describe how this key adaptation aided the animal's survival. *Hint: Look for the animals with a DNA icon to access this information.*

Main animal's name	**Age** (millions of years)	**Animal group**	**Key adaptation** (Hint: look for the DNA icon) 	**General benefit of adaptation on survival**

(D) Construct an Explanation

Name: _____

How did natural selection lead to the rise of adaptations that are still found in groups and organisms today?

How did natural selection play a role in the extinction of groups in changing environments?

(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) Surviving Extinction Survey

Name: _____

Complete the following:

1. Which of the following is an example of how natural selection works?
    a. Random mutation causes a beneficial change in an organism's DNA
    b. New organisms migrate into an area and add their genes to the population
    c. Some organisms have traits better suited to their environment than others
    d. Due to chance events, some organisms survive while others are wiped out

2. About how far back in evolutionary history did mammals and reptiles share a common ancestor?
    a. About 1 million years ago
    b. About 65 million years ago
    c. About 320 million years ago
    d. About 540 million years ago
    e. These groups have no common ancestor

3. The image here shows a skeleton of an extinct type of cynodont.

    This animal had the following traits: It lived in a burrow; was warm-blooded; had specialized teeth; and laid eggs on land. Natural selection favored these traits and they have been passed on to which modern descendants?
    a. Mammals
    b. Birds
    c. Reptiles
    d. Fish

4. Why might an animal evolve the ability to burrow? List <u>two</u> benefits that an animal might gain from being able to burrow.

5. At times in the history of life on Earth, there have been "mass extinctions" in which many species of animals went extinct all at once. Describe one example of an environmental change that could lead to mass extinctions. What kind of adaptations would significantly decrease a group's ability to survive that environmental change? What kind of adaptations would increase a group's ability to survive?