National Aeronautics and Space Administration



The Search for Life

Middle School Lesson

The Search for Life

Grades: 6-8 **Prep Time: ~10 min** **Lesson Time: 200 - 245 minutes**



WHAT STUDENTS DO: Explore the key moments in Earth's biogeological history.

Students travel back in geologic time to explore some of the major historical events of Earth in an attempt to understand the search for life on other planets in the universe.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE AND WHAT IS EARTH'S PLACE IN IT?

NGSS Core Question: ESS1: Earth's Place in the Universe

How do people reconstruct and date events in Earth's planetary history?

NGSS ESS1.C: The History of Planet Earth

HOW CAN THERE BE SO MANY SIMILARITIES AMONG ORGANISMS YET SO MANY DIFFERENT KINDS OF PLANTS, ANIMALS, AND MICROORGANISMS?

NGSS Core Question: LS4: Biological Evolution: Unity and Diversity

What evidence shows different species are related?

NGSS LS4.A: Evidence of Common Ancestry and Diversity

Instructional Objective (IO)

Students will be able to

IO1: Construct an argument about the constraints and limitations regarding the search for life in the universe using evidence from Earth's rock record.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

1.0 Materials

Required Materials:

Please Supply:

- Computer or Laptop – 1 per student
  - Supported Browsers: Chrome; Edge; Firefox; Safari

Please Print:

From Student Guide

(A) Complex Life in the Universe	- 1 per student
(B) Stories in Rock	- 1 per student
(C) Visiting Deep Time	- 1 per student
(D) Extinction Story	- 1 per student
(E) Classifying Organisms by Phylogeny	- 1 per student
(F) Stromatolites	- 1 per student
(G) Searching for Life in the Universe	- 1 per student

Optional Materials:

From Teacher Guide

(B) Stories in Rock (KEY)
(C) Visiting Deep Time (KEY)
(D) Extinction Story (KEY)
(E) Classifying Organisms by Phylogeny (KEY)
(F) Stromatolites (KEY)
(G) Searching for Life in the Universe (KEY)

From Alignment Documents

(N) The Search for Life Alignment Rubrics

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

2.0 Unit Timeline

***The Search for Life* Unit Timeline**:

Time:

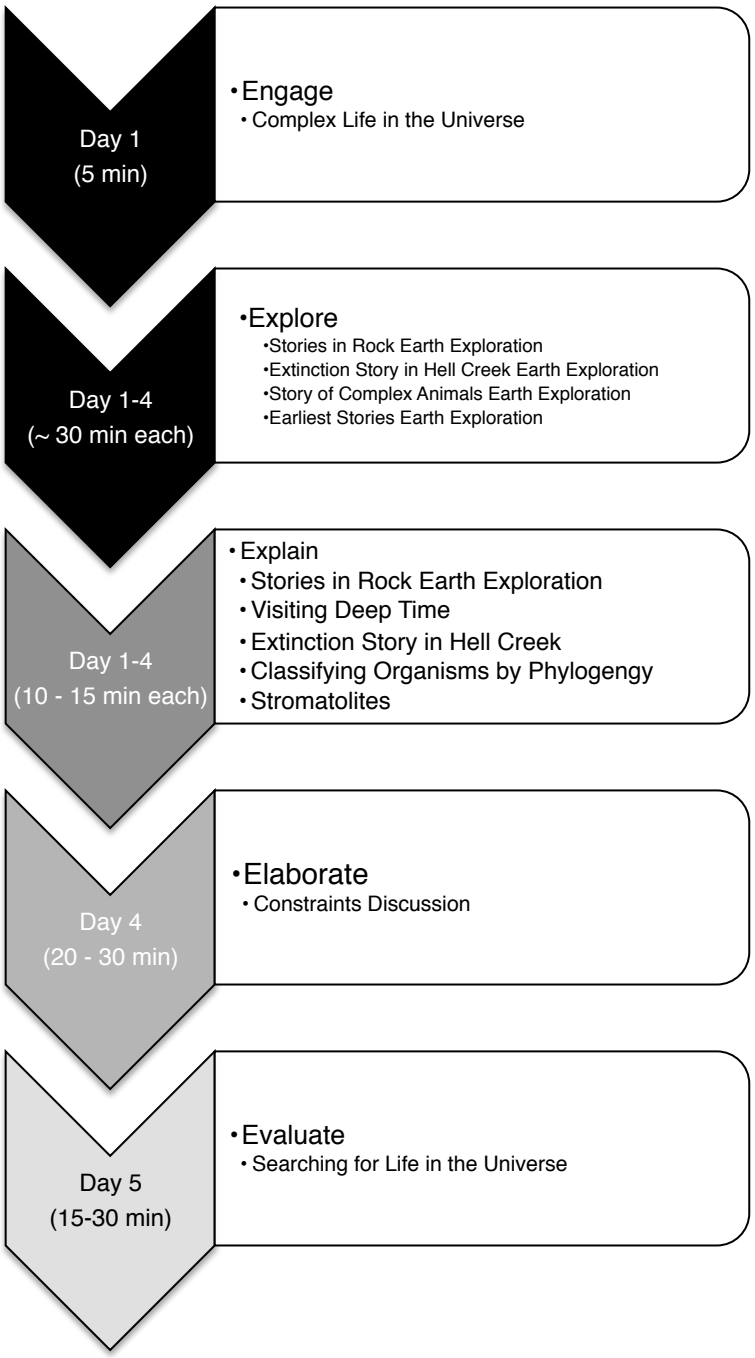
- 200 - 245 minutes

Materials:

- Student Guide pages

5-E Inquiry Process:

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



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

3.0 Vocabulary

analog	something or someplace used for comparison
analyze	consider data and results to look for patterns and to compare possible solutions
bed	a layer or rock that is distinct from other layers above and below it
carrying capacity	the maximum number of organisms of a species within a region that can be supported without damaging the environment
constraint	a limitation or restriction
cyanobacteria	single-celled, photosynthetic bacteria sometimes called blue-green algae
diversity	variability among all living organisms
empirical evidence	knowledge gained through direct or indirect observation
environment	external surroundings including living and nonliving factors
explanations	logical descriptions applying scientific information
extinction	the disappearance of a species from Earth
fossil	mineral replacements, preserved remains, or traces of organisms that lived in the past and have been preserved in Earth's crust
habitable	suitable or good enough to sustain life
hominids	family of erect, bipedal primates, which includes humans and great apes
igneous rock	rock that is formed through the cooling and solidification of magma or lava
lamination	a series of very fine layers within sedimentary rock
limitation	a restrictive weakness or lack of capacity
metamorphic rock	previously formed rock that has been changed through heat and/or pressure
microbes	microscopic organisms including bacteria, some fungi, and protozoa; may be single-celled or multicellular
observations	specific details recorded to describe an object or phenomenon
outcrop	a rock formation that is visible at the surface
photosynthetic	relating to the process by which green plants and some other organisms use sunlight to make nutrients from carbon dioxide and water while releasing oxygen

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

predict	to declare what will happen based on reason and knowledge
phylogeny	the evolutionary development or history of a type of organism
sedimentary rock	rock formed from the cementation of material deposited in oceans or on Earth's surface
stromatolite	a sedimentary fossil formed from layers of cyanobacteria and trapped sediment.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

4.0 Procedure

PRIOR KNOWLEDGE & SKILLS

A. Photosynthesis
B. Rock Cycle
C. Natural Selection
D. Adaptation

PREPARATION

A. Reserve computers or tablets for exploration days.

B. Visit the links below for access to the digital learning experiences and additional resources.

C. Enroll students in each lesson for *The Search for Life* unit if you would like to make their progress available outside of class and track the analytics of their learning behavior. The entire unit contains the following lessons:

a. Stories in Rock
b. Extinction Story
c. Story of Complex Animals
d. Earliest Stories

D. PRINT THE FOLLOWING:

- Student **Recording Sheets (A-G)** – 1 per student

STEP 1: ENGAGE (~5 minutes)

Set Up the Search for Life Unit

A. Prior to starting the lessons, hand out ***(A) Complex Life in the Universe Recording Sheet*** and have students answer the questions to demonstrate their current understanding of the search for life.

B. Hand out or assign computers and ask students to access the Stories in Rock lesson linked above. If students have been enrolled, they will have a link in their email inviting them to the lesson.

STEP 2: EXPLORE (120 minutes for all four sections)

The Search for Life Earth Explorations

A. Students will complete their exploration of Earth's history in sections, alternating between EXPLORE and EXPLAIN activities.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

- **Classroom Management Tip:** If the next class will be using the same computers and you are not enrolling students into the lessons to track progress, ask students to click the profile icon in the upper right corner and select "Restart Lesson." This will ensure your next group starts at the beginning of the Earth Exploration lesson.

- **Teacher Tip:** If students seem to be stuck in an activity, it isn't responding in a way that seems correct, or if an error occurs, students can attempt to refresh their browser or click the profile icon in the upper right corner and select "Restart Lesson." "Restart Lesson" will clear all of their progress and bring them back to the start screen. Hitting the browser's "Refresh" button will not restart the activity.

- **Teacher Tip:** If you would like to analyze student interactions in this activity, you can sign up to join the Infiniscope Teaching Network and enroll your class into the activity. By enrolling, you will gain access to the analytics of the activity by student to see how students progressed through the activity. You also have the ability to adopt the activity and adapt it to the specific needs of your classroom, school, or community.

STEP 3: EXPLAIN (~ 40 - 60 minutes)
Evidence from Deep Time

A. Hand out ***(B) Stories in Rock Recording Sheet.*** Students will complete this recording sheet as they work through *The Stories in Rock* lesson.

B. Hand out ***(C) Visiting Deep Time Recording Sheet.*** Students will make predictions then complete the recording sheet as they work through *The Stories in Rock* lesson.

C. Hand out ***(D) Extinction Story Recording Sheet.*** Students will complete this recording sheet as they work through the *Extinction Story* lesson.

D. Hand out ***(E) Classifying Organisms by Phylogeny Recording Sheet.*** Students will complete this recording sheet as they work through the *Story of Complex Animals* lesson.

E. Hand out ***(F) Stromatolites Recording Sheet.*** Students will complete this recording sheet as they work through the *Earliest Stories* lesson.

STEP 4: ELABORATE (~ 20 - 30 minutes)
Constraints in the Search for Life

A. Lead a discussion or assign research to identify the limitations in our search for life. Examples of this discussion or results of the research may include:

a. **Limitations in technology** – How far we can see into the universe is limited by the technology we currently have. Most exploration tools collect, analyze, and

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program. *The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.*

record light from objects in the universe. Telescopes, spectrographs, and cameras may be ground based or mounted on spacecraft traveling through space. Spectrographs allow astronomers to analyze light to determine the temperature and composition of distant objects including the atmospheres of planets potentially providing indirect evidence of life.

b. **Limitations in human capacity** – There is a lot of sky to survey in the search for life. The farther from Earth you go, the more difficult it is to survey due to the expanded radius of the search. Without direct communication with intelligent life on another planet, humans would need to explore a potentially habitable planet via orbital imagery or rover imagery just as we do in our own solar system. However, the most effective means in the search for life is sending humans to explore the way we do here on Earth. It takes a long time and sophisticated equipment to send satellites, rovers, and humans to other worlds, so humans have never explored past our own moon. It takes about 300 days to get to Mars, one of our closest neighbors in the solar system. In addition to the time factor, crewed missions require sophisticated equipment and extensive mission control teams to ensure human safety and success of a mission. The financial burden of such missions also limits direct human exploration of other worlds.

c. **Limitations posed by nature** – Current forms of technology analyze the light coming from potentially habitable worlds that may be hundreds to thousands of light years away. The data we collect is limited due to both the distance and the time travelled. The farther into space we explore, the further back in time we are observing. For example, the light we see today from stars and planets 2,000 light years away is 2,000 years old. We are literally observing that world as it was 2,000 years ago. Those worlds and the life on them may have evolved in that amount of time. If intelligent life exists on one of those worlds, the communication they produce may travel slowly and hasn't reached us yet.

STEP 5: EVALUATE (~ 15 - 30 minutes)

Evaluate The Search for Life

A. At the conclusion of *The Search for Life* unit and the constraints/limitations conversation, hand out ***(G) Searching for Life in the Universe Recording Sheet***. Students will revisit the concept of the search for life in the universe, applying all concepts from the unit to draw a conclusion.

5.0 Evaluation/Assessment

Use the *(N) Searching for Life Alignment Rubric* as a formative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the Learning Outcomes (LO) identified in the Alignment Documents for the activity.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

6.0 Extensions

1. NASA's Exoplanet Exploration
2. NASA's Search for Life
3. James Webb Telescope
4. TESS
5. Kepler Telescope

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(A) Complex Life in the Universe Recording Sheet

Name: _____

Complete the following before starting The Search For Life Unit.

NASA is searching for life in the universe, as evidenced by missions such as the Kepler Space Telescope, K2 telescope, TESS, and the James Webb Space Telescope. These missions focus on the search for potentially habitable worlds. What kind of life are we looking for? How will we know we found life?

> *"If we find lots of planets like ours…we'll know it's likely that we aren't alone, and that someday we might be able to join other intelligent life in the universe."*
> - William Borucki, principal investigator for NASA's Kepler mission

1. When you hear the phrase "search for life," what does that mean to you?

_____

_____

_____

_____

2. What do you think is the likelihood of discovering intelligent life in the universe? Why?

_____

_____

_____

_____

_____

_____

_____

_____

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(B) Stories in Rock Recording Sheet

Name: _____

Complete the following as you work through the *Stories in Rock* lesson.

1. Based on what you have learned from *Stories in Rock*, explain the processes scientists use to determine the age of fossils, rocks, and events captured in the fossil record.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(C) Visiting Deep Time Recording Sheet

Name: _____

Make predictions then gather evidence during the *Stories in Rock* lesson.

Shortly you will travel through time to make observations about life in different time periods. Before you begin your journey, take a moment to consider what you might see at each time period. What will the environment look like? What kinds of organisms exist? Record your predictions below.

During the lesson, record features of the environment and the types of organisms that exist in each time period.

Before Exploration Predictions	After Exploration Evidence
3.5 billion years ago	3.5 billion years ago
560 million years ago	560 million years ago
65 million years ago	65 million years ago

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(D) Extinction Story Recording Sheet

Name: _____

Complete the following as you work through the *Extinction Story* lesson.

2. Explain the significance of the K-Pg boundary and the evidence contained in Hell Creek that demonstrates the significance of this boundary.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program. *The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.*

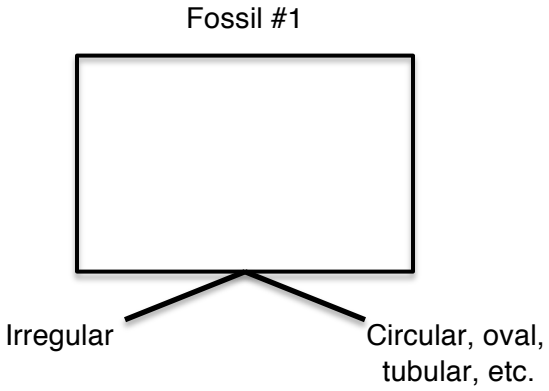
Last edited: November 1, 2018

(E) Classifying Organisms by Phylogeny Recording Sheet (1 of 2)

Name: _____

Complete the following as you work through the *Story of Complex Animals*.

Create a dichotomous key for one of the fossils in Nilpena. In the box, draw your best representation of the fossil you have selected. After selecting the shape in the lesson, draw and label each decision point as you work through the characteristics to identify your fossil. Write the name (*Genus*) of your fossil next to your drawing.



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

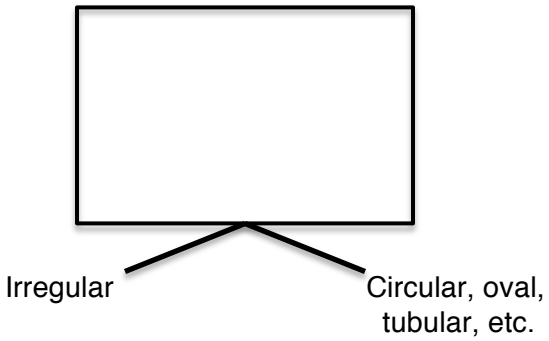
(E) Classifying Organisms by Phylogeny Recording Sheet (2 of 2)

Name: _____

Complete the following as you work through the *Story of Complex Animals*.

Create a dichotomous key for one of the fossils in Nilpena. In the box, draw your best representation of the fossil you have selected. After selecting the shape in the lesson, draw and label each decision point as you work through the characteristics to identify your fossil. Write the name (*Genus*) of your fossil next to your drawing.

Fossil #1



This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(F) Stromatolites Recording Sheet

Name: _____

Complete the following as you work through *Earliest Stories*.

3. What are stromatolites? What evidence points to their existence in North Pole Dome, Australia? How are stromatolites significant in the story of life on Earth?

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(G) Searching for Life in the Universe Recording Sheet

Name: _____

Complete the following at the conclusion of *The Search for Life* unit.

Based on your experience in *The Search for Life* Unit, construct an argument for what type of life we are most likely to find during our search of the universe, how likely are we to find intelligent life, and the possible constraints related to this search? Include reference to the bulls-eye and what it represents in your response.

_____

_____

_____

_____

_____

_____

_____

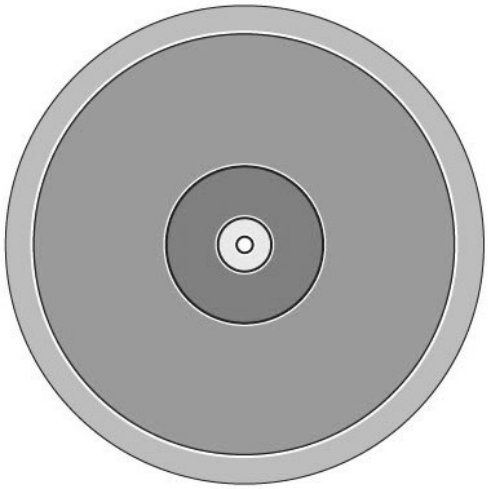
_____

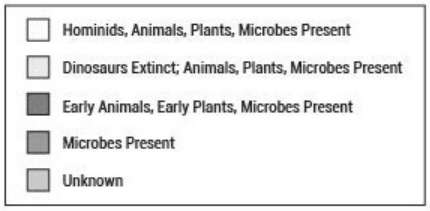
_____

_____

_____

_____





_____

_____

_____

_____

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(B) Stories in Rock Recording Sheet (KEY)

Complete the following as you work through the *Stories in Rock* lesson.

1. Based on what you have learned from *Stories in Rock*, explain the processes scientists use to determine the age of fossils, rocks, and events captured in the fossil record.

   Scientists use radiometric dating to establish the age of igneous rocks. The law of superposition (layers at the bottom are older than the layers at the top) is then used to establish the relative age ranges of the rocks in between. When the rocks in between radiometrically dated layers contain fossils, scientists use these ranges to establish the time periods these organisms existed on Earth.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(C) Visiting Deep Time Recording Sheet (KEY)

Make predictions then gather evidence during the *Stories in Rock* lesson.

Shortly you will travel through time to make observations about life in different time periods. Before you begin your journey, take a moment to consider what you might see at each time period. What will the environment look like? What kinds of organisms exist? Record your predictions below.

During the lesson, record features of the environment and the types of organisms that exist in each time period.

Before Exploration Predictions	After Exploration Evidence
	Organisms: • *Cyanobacteria* • *Single-celled photosynthetic organisms.* *Environment* • *Shallow oceans with very little oxygen*
3.5 billion years ago	3.5 billion years ago
	Organisms: • *First multicellular organisms* *Environment* • *Shallow marine environment* • *Subtidal zone*
560 million years ago	560 million years ago
	Organisms • *Large vertebrates such as dinosaurs* • *Extinction event of dinosaurs* • *Small mammals before and after extinction* *Environment* • *None recorded*
65 million years ago	65 million years ago

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(D) Extinction Story Recording Sheet (KEY)

Complete the following as you work through the *Extinction Story* lesson.

2. Explain the significance of the K-Pg boundary and the evidence contained in Hell Creek that demonstrate the significance of this boundary.

The K-Pg boundary represents a major division in geologic time. It is the boundary between the Cretaceous and the Paleogene. What makes this event significant is that it marks a major extinction event 66.04 million years ago. This extinction event marks the end of the dinosaurs and many other organisms, but also marks the rise of mammals. Here in Hell Creek we see a layer of clay containing iridium, which supports the asteroid impact hypothesis at this extinction boundary. Below the iridium layer, we find a dinosaur, Triceratops to be specific. Below and above the boundary, small mammals and reptiles can be found indicating they survived the extinction event that the dinosaurs did not.

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(E) Classifying Organisms by Phylogeny Recording Sheet (KEY)

Complete the following as you work through the *Story of Complex Animals*.

Create a dichotomous key for one of the fossils in Nilpena. In the box, draw your best representation of the fossil you have selected. After selecting the shape in the lesson, draw and label each decision point as you work through the characteristics to identify your fossil. Write the name (*Genus*) of your fossil next to your drawing.

1.
   a. Fossil is irregular and looks like patches of wrinkles, grooves, or bubbles on the bed surface – ***Go to 2***
   b. Fossil is circular, oval, tubular, or some other distinct shape on the bed surface – ***Go to 4***
2.
   a. Irregular surface pattern of rod-shaped depressions in random orientations – ***"Groove" Textured Organic Surface (TOS)***
   b. Irregular surface with fine to coarse, bumpy ridges, a bubbly pattern or a wrinkled, skin-like texture – ***Go to 3***
3.
   a. Irregular surface with patches of wrinkled, skin-like texture (often on ripple marks) - ***"Elephant Skin" Textured Organic Surface (TOS)***
   b. Irregular surface with patches of crinkled or bubbly texture with depressions and peaks - ***"Pucker" Textured Organic Surface (TOS)***
4.
   a. Fossil is circular, oval or anchor-shaped – ***Go to 5***
   b. Fossil is tubular or feather-shaped – ***Go to 10***
5.
   a. Circular to oval in shape with circular ridges, arms, or segments in the center or at the edge – ***Go to 6***
   b. Anchor-shaped with an arched ridge on the head connected to a ridge down the middle – ***Parvancorina***
6.
   a. Circular to oval in shape with circular ridges or segments in the center – ***Go to 7***
   b. Circular to oval in shape with arms in the center or arms around edge – ***Go to 8***
7.
   a. Circular to oval in shape with segments in the center – ***Dickinsonia***
   b. Circular to oval in shape with concentric ridges and/or lobes in the center – ***Aspidella***

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

8.
   a. Circular to oval in shape with a fringe of arms around the edge of the body - ***Medusoid (jellyfish)***
   b. Circular to oval in shape with three to eight spiral arms in center of body – ***Go to 9***

9.
   a. Circular to oval in shape with three spiral arms in the center of body – ***Tribrachidium***
   b. Circular to oval in shape with eight spiral arms in the center of body - ***Eoandromeda***

10.
   a. Fossil is tubular, beaded often in clusters - ***Funisia***
   b. Fossil is feather-shaped – ***Go to 11***

11.
   a. Fossil is feather-shaped with a distinct head and worm-like body with segments – ***Spriggina***
   b. Fossil is feather-shaped with a stalk and disc-like holdfast - ***Charniodiscus***

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

(F) Stromatolites Recording Sheet (KEY)

Complete the following as you work through *Earliest Stories*.

3. What are stromatolites? What evidence points to their existence in North Pole Dome, Australia? How are stromatolites significant in the story of life on Earth?

   Stromatolites are layered, sedimentary rock formations created by photosynthetic cyanobacteria. These single-celled organisms formed microbial mat communities. Layered features were originally formed by the growth of layer upon layer of cyanobacteria. These communities excrete mucus coatings that trap sand into layers of sediment. The cyanobacteria community will build new microbial mats on top of sediment layers. Over time the layers upon layers of cyanobacteria and sediment can become fossilized and record the presence of the photosynthetic bacteria. Here in North Dome, we see many of these layered features that scientists identify as stromatolites dating from 3.5 billion years ago. This fossil evidence is significant because these single-celled, photosynthetic organisms living as a community are responsible for the rise of oxygen in the early atmosphere of Earth.

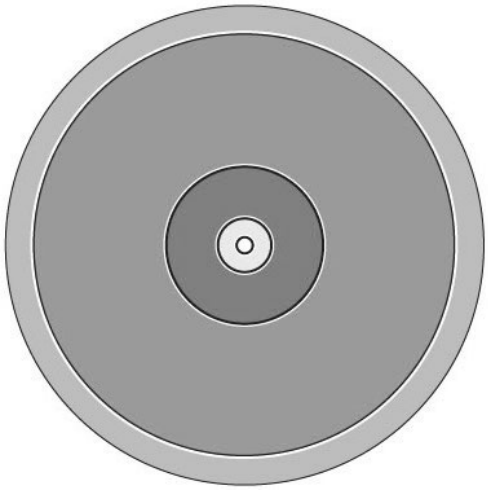
This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

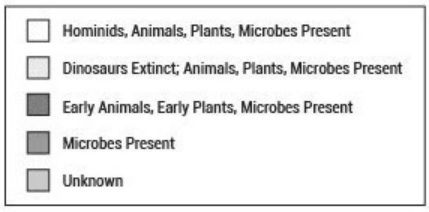
(G) Searching for Life in the Universe Recording Sheet (KEY)

Based on your experience in *The Search for Life* Unit, construct an argument for what type of life we are most likely to find during our search of the Universe, how likely are we to find intelligent life, and the possible constraints related to this search? Include reference to the bulls-eye and what it represents in your response.

Students should respond that we are more likely to find single–celled organisms like cyanobacteria in our search for life because a larger portion of the bullseye representing geologic time is consumed with this type of life. It is highly unlikely to find intelligent life based on current limitations.



Possible constraints they may choose to discuss here are related to your discussion:



a. ***Limitations in technology*** *– How far we can see into the universe is limited by the technology we currently have. Most exploration tools collect, analyze, and record light from objects in the universe. Telescopes, spectrographs and cameras may be ground based or mounted on spacecraft traveling through space. Spectrographs allow astronomers to analyze light to determine the temperature and composition of distant objects including the atmospheres of planets potentially providing indirect evidence of life.*

~~b.~~ ***Limitations in human capacity*** *– There is a lot of sky to survey in the search for life. The farther from Earth you go, the more difficult it is to survey due to the expanded radius of the search. Without direct communication with intelligent life on another planet, humans would need to explore a potentially habitable planet via orbital imagery or rover imagery just as we do in our own solar system. However, the most effective means in the search for life is sending humans to explore the way we do here on Earth. It takes a long time and sophisticated equipment to send satellites, rovers, and humans to other worlds, so humans have never explored past our own moon. It takes about 300 days to get to Mars, one of our closest neighbors in the*

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018

solar system. In addition to the time factor, crewed missions require sophisticated equipment and extensive mission control teams to ensure human safety and success of a mission. The financial burden of such missions also limits direct human exploration of other worlds.

c. ***Limitations posed by nature*** *– Current forms of technology analyze the light coming from potentially habitable worlds that may be hundreds to thousands of light years away. The data we collect is limited due to both the distance and the time travelled. The farther into space we explore, the further back in time we are observing. For example, the light we see today from stars and planets 2,000 light years away is 2,000 years old. We are literally observing that world as it was 2,000 years ago. Those worlds and the life on them may have evolved in that amount of time. If intelligent life exists on one of those worlds, the communication they produce may travel slowly and hasn't reached us yet.*

This material is based upon work supported by NASA under cooperative agreement No. NNX16AD79A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration. This lesson was prepared by Arizona State University's Education Through eXploration (ETX) Center. Lesson formatting was adopted and adapted from Arizona State University's Mars Education Program.
The lesson and its' associated materials may be photocopied and distributed freely for non-commercial purposes. Copyright 2016-2021.

Last edited: November 1, 2018