EXPLORING ASTROBIOLOGY

Fossils : Ancient Storytellers

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OVERVIEW	This lesson is designed to explore astrobiology from a futuristic and a past perspective, as well as from an interdisciplinary approach. Students will learn about ancient fossils and the stories they leave behind. They will consider what life is, what life was, and what life will be in the future, and how that might be reflected in a fossil record. **Duration: about two hours (but can be extended or shortened according to need)**
LEARNING OBJECTIVES	• Define astrobiology as an interdisciplinary science. • Explain what fossils are and how they form. • Identify different types of fossils and what they reveal about past environments. • Connect Earth's fossil record to the search for life on other planets. • Use creativity and evidence-based reasoning to interpret fossils as "stories" from the past.
ARIZONA STANDARDS	• **3rd Grade**: 3.L1U1.5 Develop and use models to explain that plants and animals (including humans) have internal and external structures that serve various functions that aid in growth, survival, behavior, and reproduction. • **4th Grade**: 4.L4U1.11 When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. • **5th Grade**: 5.L3U1.10 The environment also affects the traits that an organism develops. Differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently. • **6th Grade**: 6.L2U1.13 Develop and use models to demonstrate the interdependence of organisms and their environment, including biotic and abiotic factors. • **7th Grade:** 7.L1U1.11 Construct an explanation for how organisms maintain internal stability and evaluate the effect of the external factors on organisms' internal stability. • **8th Grade:** 8.L4U1.12 Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions.
NEXT GENERATION SCIENCE STANDARDS	**3rd Grade:** 3-LS3-2 Use evidence to support the explanation that traits can be influenced by the environment. 3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. **Middle School:** MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

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MATERIALS	• Powerpoint Lesson • Clay (air dry clay, modeling clay, play doh, etc.) • Tray or space for drying clay fossils • (Optional) Clay sculpting tools, toothpicks, skewers, plastic knifes, or any other items that might be used for shaping. • (Optional) Fossil collection; to show students what fossils may look like.
BACKGROUND KNOWLEDGE	• Life interacts with the enviornment and may leave remains behind. • Earth is very old - more than 4 billion years old! • Humans have only existed for a small fraction of Earth's time. • Surface features change over long periods of time (oceans, deserts, mountains were not always the same as they are today). • Earth is a planet, other planets also orbit the sun and their distance affects their conditions.
VOCABULARY	• Astrobiology — The study of life in space and whether living things could exist on other planets. • Fossil — The preserved remains or traces of a plant or animal from long ago. • Fossilization — The process where plants or animals slowly turn into fossils over a very long time. • Biosignatures — Clues or signs that may show life existed or still exists somewhere. • Stromatolites — Layered rock structures made long ago by tiny living organisms called microbes. • Environment — The surroundings and conditions where a living thing lives. • Evidence — Facts or clues that help prove something is true. • Habitability — How suitable a place is for living things to survive there. • Analogs — Things that are similar in important ways and can help us understand something else.
SET UP	For easier transition to clay molding time during presentation, prepare "clay kits" beforehand and have them set aside and ready to distribute when the clay activity begins. Each "kit" should include a lump of clay and tools for each student.
LESSON PROCEDURE	**Warm Up (2-15 minutes)** 1. The warm up introduces the activity, can be just a few minutes, or up to 15 minutes. 2. **Warm Up Questions (Slide 2 on Powerpoint)** • Explore some or all of the questions on the slide. • You might choose to have this as a silent bell ringer activity, discuss in small groups, discuss as a class, or some combination of these.

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LESSON PROCEDURE

Discussion 1: Ancient Fossils (15 - 30 minutes)

- Introduce Astrobiology as an idea, and as a scientific field (**slide 3).** Ask the students how they think Astrobiology is related to fossils.
- Introduce students to some of the areas that astrobiology studies **(slide 4, 5, 6)**
  - Note that these are not the only areas of study. Other areas include: astromaterials and terrestrial material analysis, extreme environments, exoplanet atmospheres, lunar studies, volcanism in other planets, asteroid and comet studies, origin of our solar system, origin of planets etc.
- Pause on Slide 6 to discuss the similarities and differences between paleontologists and astrobiologists.
  - Both study the history of life on Earth through fossils, seeking to understand how life began, how life evolved over time, and how some life went extinct.
  - Astrobiologists look to extend this knowledge to explore the possibility of life on other planets, and also what Earth life might be like in the future.
  - Explain that astrobiology is an interdisciplinary field, and it uses tools and techniques from many fields, including paleontology! Astrobiology can apply an astrobiological perspective to any field of study.
- Introduce students to the definition of the term "fossils" **(slide 7)**. Explain to students how fossilization occurs, and what steps need to happen for something to become a fossil **(slide 8)**.
- Explain to students that life evolves and adapts over time **(slide 9).**
  - One of the reasons we know this is because of the fossils we have found.
  - When an organism finds an optimal way to survive, they stick to that.
  - When an environment changes, the organisms might evolve over many generations to adapt to those changes.
  - Examine the fossils and bones on Slide 9. Why did this organism change over time? What might have changed in its environment to cause it to evolve over many generations to have legs instead of fins?
- Explain to students how not all fossils are bones (**slide 10**), and there are different types of fossils.
  - **Preserved Remains**: Perhaps an organism fell in a pool of amber and it was unable to get out so it remained preserved. In ice, perhaps an organism was hurt and fell in a lake, and if climate was cold and lake froze, the organism would be trapped in the ice. There are natural tar pools in nature that also preserve organisms (such as the La Brea Tar Pits).

LESSON PROCEDURE

- **Trace fossils** show us what the organism was doing, rather than parts of the actual organism. Footprints, tunnels, and poop are examples of trace fossils.
- **Cast and mold fossils**: You can compare the mold to when we make imprint of a coin on playdoh. If we press the coin to the playdoh and remove it, we have a mold. A cast can be compared to when you use a castle mold and take it to the beach. When you fill in the mold of the castle with sand and lift the mold, you are left with a cast in the shape of a sand castle.
- **Body Parts**: Bones, shells or wood that can be petrified or fossilized and hardened over time.

- If you hace a collection of real fossils, bring them out and allow students to look at them and talk about their features. Ask questions like:
  - How do you think this fossil was formed?
  - What can we learn about the past from this fossil?
  - What organism features could you study with this fossil?

Clay Activity 1 (15-25 mins)
Transition to the clay activity and pass out "clay kits" to the students.

- Encourage students to create a fossil based on:
  - Ancient animals
  - Plants (leaves, roots)
  - Footprints or trace fossils
  - Or invent a fossil that tells a story meaningful to them
- Encourage students to consider the types of fossils they learned about and to explore any of the types they find interesting.

While students work on their fossils, walk around and use guiding prompts such as the following, to engage students in connecting their artwork to what they just learned.

- What kind of organism made this fossil?
- What environment did it live in?
- What does this fossil reveal about that world?
- What does this fossil say about the life of the organism and its behavior?

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LESSON PROCEDURE

Discussion 2 (15-30 mins)

- Continue on to **slide 12.** Introduce stromatolites, layered structures built by microscopic bacteria over millions of years.
  - Stromatolites are some of the oldest fossils on Earth. They have been dated to be 3.5 billions years old. From studying these structures we can see into the past and understand how early life survived when Earth was very young, hot and extreme.
  - Stromatolites are able to release oxygen bubbles, and in the past they filled the ocean with oxygen. The oxygen was then released into the air, which allowed more organisms to use oxygen, and allowed more life to flourish. We breathe oxygen now, but oxygen wasn't always available. Stromatolites were crucial in creating oxygen on Earth.
- In **slide 13,** introduce what a biosignature is.
  - A biosignature refers to any feature that tells you something is alive, or was alive. Stromatolites are considered biosignatures of Earth. They are evidence of past and current life.
- In **slide 14**, connect stromatolites to life beyond Earth.
  - Explain that if something similar was found somewhere else, that could be evidence of past life.
  - Introduce leopard spots found on Mars. These "leopard spots" are thought to be sedimentary structures in an area on Mars that was once full of water.
  - From what we know about stromatolites, they need water to survive. Point out to the image of a collapse stromatolite dome under water, and how similar it looks to the recently found leopard spots. Scientist think these leopard spots could be a **potential** sign of past life on Mars.
  - Introduce exoplanet K2-18b, a planet about 8.6 times more massive than Earth. In 2015, the James Webb Space Telescope detected methane, carbon dioxide and a hydrogen-rich atmosphere. It also may have detected a chemical compound called dimethyl sulfide, which on Earth is only produced by marine microorganism. But, dimethyl sulfide can also be made when light interacts with other elements, so we can't know for sure. But, it is exciting to think about the possibilities.
- **In slide 15,** connect fossils to the information they can give us.
  - **Geochronology** (tree ring dating) is one example. Trees can tell us information about their life; they store it in their tree trunks as rings, bands and patterns. In tree rings, you can see information about droughts, floods, wildfires, and even scars made to the tree.
  - Explain to students the importance of context of fossils, such as the place they are found. This can tell us how Earth's conditions have changed over time.
- Continue the connection to context of fossils in **slide 16.** Explain that Earth has gone through many changes, and fossils help us learn about these changes. For instance, in Egypt there is a place where they have found anywhere from 400 to 1000 fossils of whales. How can these whales all be found in the middle of a desert? Point out that millions of years ago, Egypt was once part of an ocean, this would make sense to why we see whale fossils there today.

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LESSON PROCEDURE

- In **slide 17,** we ask the question "What story is astrobiology trying to understand?"
  - Explain that the story astrobiology is trying to understand is still unknown. We don't know how we got here, or where else life might be.
  - In Mars, we have two active rovers, Perseverance and Curiosity, they each have their own tasks and purposes. They continue to look for signs of past or present life, and help us understand if life exists on Mars, or if existed there in the past.
- In **slide 18,** we continue with topics of astrobiological work.
  - We are able to use our own planet as a laboratory using research analogs - locations on Earth that are similar to other locations beyond Earth.
  - Astrobiology is all about exploring! Scientists will continue to explore our solar systems with more instruments and missions. In our solar system, we have several places that are of interest, such as Europa, a moon of Jupiter, which has a subsurface liquid ocean under its icy crust. We also look beyond our solar system using instruments such as the James Webb Space Telescope.
- In **slides 19 and 20,** prompt students to think about what a different world would look like, with Titan (Saturn's moon) as an example.
  - If it were present life, what would it look like?
  - How does the environment influence the organism and its behavior?
  - If it were past life, would there be fossils? What would they look like?
- In **slide 21,** introduce the retrospective questions of what would our fossils from today tell the world of the future. What would it say about us?
  - What would people learn from our fossils and the things we leave behind?

Clay Activity 2 (15 - 25 minutes)

Transition to clay time for a second time, this time have them choose one of the following scenarios:

1. If someone studied Earth millions of years from now...
   - What fossils would represent our time?
   - What would they learn about humans?
2. If life existed on another planet:
   - What might its fossils look like?
   - How would fossilization differ in ice, low gravity, or no atmosphere?
3. If humans visited another planet:
   - What evidence might **we** leave behind?

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LESSON PROCEDURE

Reflection (15 minutes)

For Middle School Level:

- What is a fossil, and why do scientists study them?
- How can a fossil tell us about the environment an organism lived in?
- What is one example of a fossil that is not a bone?
- Why do you think fossils are rare, even though many organisms have lived on Earth?
- How can studying fossils on Earth help scientists search for life on other planets?
- Imagine you are a scientist in the future. What would you learn about today's world from our fossils?

For High School Level:

- How do fossils act as both biological and environmental records?
- Why are microbial fossils especially important when searching for life beyond Earth?
- What makes a structure or chemical pattern a strong biosignature?
- How do Earth analog environments help astrobiologists interpret data from other planets?
- What limitations do fossils have as evidence for past life?

EXTENSIONS AND TAKE HOME ACTIVITIES

- This lesson can be accompanied by show and tell of a collection of fossils.
  - This can be done during the lesson, as a separate activity and/or in previous lesson as preparation for this one.
- This lesson can also be supplemented/accompanied by educational paleontology related videos, for students to have a more visual idea of fossils.
  - Such as:
    - What are fossils? (Paleontology)
    - What are fossils (Types of Fossils)
- If there is a natural area near your school, you might have students collect natural materials (such as sticks and leaves) to create fossil imprints in clay as part of Clay Activity 1.
- This lesson can be integrated with art class objectives, as an art showcase of fossils from the past and future.