Astrobiology, OSIRIS-REx and The Search for the Origins and Nature of Life

Standards
Arizona
8.L4U1.11 Develop and use a model to explain how natural selection may lead to increases and decreases of specific traits in populations over time.

8.L4U1.12 Gather and communicate evidence on how the process of natural selection provides an explanation of how new species can evolve.

Materials

- PPT slides for use during the lesson.
- Data from missions about the environment of other planets or bodies in the Universe. Provided with the lesson.
- Student structured note-taker sheets.
- Computers and Internet connection for student use
- Projector/computer for PPTs and video display

Background Knowledge

Students should have basic knowledge of the following:
- The mechanism of inheritance and heredity.
- Natural selection can favor certain traits within a population.
- Populations can evolve over time in response to their environment.
- Basic knowledge of how to read data and graphs.
- Background knowledge about why Earth has an environment that allows life to exist and some extreme forms of life that live on Earth.

Overview

By delving into the realm of Astrobiology research, students will explore how scientific choices are shaped when investigating the origins of life on Earth and beyond. Through this lesson, students will analyze data, enabling them to discern strategic locations to direct origin-of-life research efforts. The OSIRIS-REx Asteroid Return Mission is highlighted as a NASA/University of Arizona mission with origins of life research as one of its scientific goals.

Goals

- Understand how Astrobiology can help humans understand the origins of life on Earth.
- Learn how our current understanding of how life evolved on Earth influences how astrobiologists study possible life beyond Earth.
- Use Data to select where and why we might explore astrobiological questions in space and plan missions.
- Learn about the role of the NASA and University of Arizona OSIRIS-Rex asteroid sample return mission and its possible contributions to Astrobiology research.

Vocabulary

- Astrobiology: (noun) the scientific study of life in the Universe. It explores questions about life's origin, evolution, and potential distribution on other planets, moons, and celestial bodies beyond Earth.
- Evolution: (noun) the process by which different living organisms are thought to have developed and diversified from earlier forms during the history of the Earth.
- Asteroid: a small rocky object that orbits the Sun, primarily found in the asteroid belt between Mars and Jupiter. They vary in size, from tiny particles to larger bodies, and are remnants from the early days of our solar system.
- Meteorite: a piece of rock or metal that falls from space and lands on Earth's surface. It comes from asteroids or other celestial bodies and can vary in size from tiny fragments to larger masses.
- Biosphere: refers to all the places in the Universe where life exists, including Earth and any other planets, moons, or celestial bodies that may support living organisms.
- Organic compounds (noun): type of molecule that contains carbon atoms bonded together, often combined with other elements like hydrogen, oxygen, nitrogen, or sulfur. Organic compounds are the building blocks of living things and play essential roles in many chemical processes.
- Carbonaceous chondrites: special rocks from space that contain carbon, a key ingredient for life. They are time capsules from the early solar system, helping scientists learn about how planets formed and how life might have started.
- OSIRIS-REx mission: a NASA spacecraft mission led by the University of Arizona designed to study and collect a sample from an asteroid named Bennu. One of its main goals is to learn more about the origins of our solar system and the potential for life on other celestial bodies.

Setup

Plan for digital access to lesson slideshows, structured notes, data sets, and video projection for OSIRIS-REx videos. Students can view and use the included structured note-takers that are included. These materials may also be printed. Student work can be completed on physical handouts or electronic notes.

Lesson Procedure

This lesson takes approximately 90 minutes. It can be used in an extended block schedule class or two 45-minute class periods.

1. *(Sides 1-5)* Following a short introductory bell work activity (at the teacher's discretion), students are provided an outline of the class period and the lesson objective and vocabulary list (included in structured notes. (Pg. 1 of structured notes)
2. *(Slides 6-7)* Review: *Earth as a model.* The teacher provides a short review of the relationships between the environmental conditions and characteristics of life on Earth conditions factors we might look for to discover life beyond Earth. Students record notes in their structured notes during this time for reference later. (Pg. 1 of structured notes)
3. *(Slides 8-9)* Group Brainstorm: What environmental factors on Earth influence life and natural selection on Earth?
   a. Students are placed into groups of 3-4 and will use previous knowledge of how Earth's environment makes it a suitable location for life.
   b. Groups brainstorm what they already know about Earth's environment and what environmental factors might influence natural selection on Earth. (Pg. 1 of structured notes)
   c. Groups will then use their knowledge of Earth's environment to predict what real Astrobiologists would use to decide where to look for origins of life information. (Pg. 1 of structured notes)
4. (*Slides 10-11)* Group Activity and Class Share—*Looking to Space*
   a. Small group discussion, students discuss and list in their notes what clues, i.e., environmental characteristics, Astrobiologists should be looking for and thinking about when they search for life!

5. (Slides 12-15) Be An Anstrobiologist: Groups study data collected about various bodies in space. The goal is to choose mission targets that would be helpful to astrobiologists—to collect evidence about the origins of life on Earth and the nature/possibility of life beyond Earth. Each group uses the data provided in the structured notes on page 5 to complete this part of the activity.

   a. Students should use the information they listed about Earth's environment to make decisions and discuss their ideas about space missions that would be beneficial for collecting information about the origins of life and potential suitability for finding signs of life as we know it. Students should also consider practical/logistical factors such as distance to these targets. (Pg. 2 of structured notes)
   b. Class share: Following the analysis of data and the selection of possible targets for research, the group will discuss which targets they selected and why. (Pg. 4 of structured notes) The teacher asks each group about some of the targets they chose. Observe and point out trends in the selections.

c. Optional Projects: Group or individual project—Create a digital poster or poster board of their selected mission target. Include research questions related to astrobiology, the rationale for the choice of the target using data from the datasheet, a description of the mission, and images of the target.

5. (*Slides 16-17)* Teacher Presentation: Lead the students through a quick explanation that many of the targets in the data table they picked have also been the subject of past, current, or planned missions. (see Astrobiology Missions—NASA: https://astrobiology.nasa.gov/missions/
   a. For southern Arizona classrooms, focusing on the OSIRIS-Rex mission is important as it ties the lesson to the University of Arizona and the students' local community (Pg. 4-5 of structured notes)

Suggested beginning of Part 2

6. *(Slides 18-21)* Discussion of Space missions with the example of The OSIRIS-REx Mission and its connection to Astrobiology and UA/Arizona.
   Show videos:

NASA Finds Ingredients of Life in Fragments of Lost World

https://youtu.be/hwrV7X69ucI

OSIRIS-REx: NASA's First Mission to Deliver Asteroid Samples to Earth

https://www.youtube.com/watch?v=cYi-WRBTPho

7. *(Slide 22)* Closing--All Class Discussion
   a. Discussion Prompts or written exit ticket activity (pa 5 of structured notes)

      1) Why did scientists, including astrobiologists, choose the Asteroid Bennu as a mission target?
         Educator notes
         a) *Scientific/Astrobiology Relevance*: Bennu is a carbon-rich, primitive asteroid believed to be a relic from the early solar system. Studying its composition can offer insights into the building blocks of our solar system and potentially the origins of life. Asteroids contain organic molecules, volatiles, and amino acids. There is an interest in whether Bennu may contain compounds important for life. While we don't expect to find life on Bennu, the presence of organic compounds or prebiotic chemistry can inform astrobiology about the conditions and ingredients available in the early solar system.
         b) *Earth Proximity:* Bennu's orbit brings it relatively close to Earth, which makes it accessible for mission planning. This proximity reduces the time and resources necessary to reach and return samples from the asteroid.
         c) *Size:* Bennu's diameter is about 500 meters, which is large enough to provide a stable, albeit weak, gravitational environment. This makes

operations, including sample collection, more manageable compared to smaller asteroids which may have microgravity environments.

d) *Rotation Period:* Bennu's rotation period is conducive to spacecraft operations. Its rotation rate (roughly 4.3 hours for one rotation) means adequate time during each "day" for the spacecraft to operate and study the surface.

e) *Potential Hazard:* Bennu is classified as a Near-Earth Object (NEO) and is one of the most potentially hazardous asteroids, with a small chance of impacting Earth in the late 22nd century. Studying its physical and chemical properties can help scientists understand potential mitigation strategies for deflecting or disrupting threatening NEOs in the future.

f) *Type of surface material:* Observations of Bennu suggested the presence of a regolith-covered surface. Regolith is a layer of loose, fragmented material covering solid rock. Such a surface is conducive to the sampling technique designed for OSIRIS-REx.

g) *Resource Potential:* Understanding the composition of asteroids can also inform future efforts related to resource utilization. This concept involves extracting and using resources in space rather than launching everything from Earth.

2) What could we learn about the origins of life on Earth and life in the Universe from Bennu?

Educator notes

a) *Primordial Building Blocks:* Bennu is a carbon-rich asteroid. Carbon is a fundamental element for life as we know it. By analyzing the organic compounds on Bennu, scientists can gain insight into the types of organic chemistry present in the early solar system. This helps us understand the ingredients that are available for the origins of life.

b) *Water:* Bennu and asteroids like it are thought to have played a role in delivering water to the early Earth. Water is another crucial ingredient for life. By analyzing the isotopic composition of any water or hydrated minerals found on Bennu, scientists can compare it with Earth's water to see if there's a match, potentially supporting the hypothesis that asteroids contributed to Earth's water inventory.

c) *Prebiotic Chemistry:* Even if Bennu does not have life, it could have complex organic molecules that are precursors to life. Identifying these molecules can provide insights into the chemical pathways that lead from simple molecules to the complex molecules necessary for life.

d) *Solar System History:* By understanding the composition and history of Bennu, we can piece together the conditions present in the early solar system. This can help answer questions about where and when the ingredients for life became available and under what conditions they could have contributed to the origins of life.

e) *Potential for Life Elsewhere*: By understanding the processes and conditions that may have led to life on Earth, we can make more informed predictions about where to look for life elsewhere in our solar system and beyond. If certain conditions and ingredients are crucial for life's origins on Earth, we might prioritize looking for those same conditions on other planetary bodies.

Bennu and other primitive bodies act as time capsules from the early solar system. By studying them, we can gain insights into the conditions, processes, and ingredients that might have led to life on Earth, and this knowledge, in turn, can guide our search for life elsewhere in the Universe.

3) What are some factors or reasons you think should guide NASA and mission designers in choosing mission targets?

   Possible discussion themes/prompts

   a. Human curiosity
   b. To find other habitable planets for humans
   c. For resources—minerals, water, etc.
   d. To study potentially hazardous objects that could impact Earth in the future
   e. To learn about how planets evolved and use that information to understand Earth's processes (climate change, etc.)
   f. To see if we are alone in the Universe

4) Optional Activities:
   a. Students create 1-2 questions that can be submitted to the OSIRIS-REx team for responses.
   b. Students can conduct research about University majors and educational programs related to Astrobiology and Space Exploration *(Lesson: Careers in Astrobiology and Space Exploration)*

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Resources

Astrobiology Missions, NASA: https://astrobiology.nasa.gov/missions/
Alien Earths Project-University of Arizona https://eos-nexus.org/
OSIRIS-REx Mission

- https://www.nasa.gov/osiris-rex
- https://www.space.com/33776-osiris-rex.html
- https://news.azpm.org/p/newsc/2023/6/16/216390-the-buzz-what-to-expect-when-osiris-rex-returns-to-earth/
- NASA Prepares for Historic Asteroid Sample Delivery on Sept. 24: https://www.youtube.com/watch?v=qfEHHdUEwlI&feature=youtu.be

Mercury: NASA https://solarsystem.nasa.gov/planets/mercury/in-depth/#otp_size_and_distance
Venus/NASA: https://coolcosmos.ipac.caltech.edu/ask/48-How-strong-is-the-gravity-on-Venus-
Ceres/NASA https://solarsystem.nasa.gov/planets/dwarf-planets/ceres/overview/
Mars:

- https://solarsystem.nasa.gov/planets/mars/in-depth/#:~:text=The%20temperature%20on%20Mars%20can,Sun%20easily%20escapes%20this%20planet.;
- https://coolcosmos.ipac.caltech.edu/ask/73-How-strong-is-the-gravity-on-Mars-#:~:text=Since%20Mars%20has%20less%20mass,only%2038%20pounds%20on%20Mars.

Europa

- https://europa.nasa.gov/resources/114/daytime-temperatures-on-europa/#:~:text=The%20data%20show%20that%20midday,and%20before%20or%20after%20midday.
- https://phys.org/news/2015-09-jupiter-moon-europa.html#:~:text=Then%20there%20is%20the%20low,presents%20challenges%20for%20human%20settlement.

Bennu & Asteroids

- https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/101955-bennu/in-depth/#:~:text=Bennu%20does%20not%20appear%20to,on%20or%20under%20its%20surface.
- https://solarsystem.nasa.gov/asteroids-comets-and-meteors/asteroids/overview/?page=0&per_page=40&order=name+asc&search=&condition_1=101%3Aparent_id&condition_2=asteroid%3Abody_type%3Ailike

Pluto

- https://solarsystem.nasa.gov/planets/dwarf-planets/pluto/in-depth/#:~:text=It's%20about%203.6%20billion%20miles,largest%20of%20which%20is%20Charon.
- https://nineplanets.org/questions/how-far-is-pluto-from-earth/

Saturn

- https://attic.gsfc.nasa.gov/huygensgcms/Saturn.htm
- https://www.nasa.gov/saturn
- https://www.britannica.com/place/Saturn-planet

Ganymede: https://phys.org/news/2015-10-jupiter-moon-ganymede.html

Enceladus:https://www.open.edu/openlearn/mod/oucontent/view.php?id=69108&section=4.4#:~:text=The%20surface%20gravity%20on%20Enceladus,Enceladus%20is%20less%20than%20this.
Kepler 16b: https://exoplanets.nasa.gov/exoplanet-catalog/1814/kepler-16b/