ASTRO BIOLOGY

EXPLORATIONS IN EARTH AND LIFE SCIENCE

by Molly Malone, Dina Drits-Esser, and Louisa A. Stark

Earth's place in space makes possible the basic conditions that support life. But what about elsewhere in the universe? Do the ideal conditions found on Earth exist on another planet or moon? Are identical conditions necessary, or do organisms adapted to survive in extreme circumstances already exist? These questions have captured the imaginations of scientists across many disciplines, as well as those of writers, artists, and students of all ages.

The Astrobiology curriculum supplement materials

Astrobiology is the study of life and the possibility that habitable environments may exist beyond Earth. This field utilizes a multitude of scientific disciplines in searching for the answer to this question: Are we alone in the universe? The Astrobiology curriculum supplement materials, available for free on the Learn. Genetics website (see Resources), can help you use this high-interest hook to teach topics in Earth science such as the atmosphere, carbon and water cycling, plate tectonics, and Earth's place in a habitable zone. The materials also connect to the life-science topics of adaptations and the requirements for life. The activities are designed to enrich any existing Earth- and life-science lessons teachers might already have planned.

The Astrobiology materials, developed by the Genetic Science Learning Center at the University of Utah, are appropriate for U.S. grades 7–12. They consist of two interactive, online animations that explore the fundamental conditions that make life possible on Earth and describe organisms that are able to survive in Earth's extreme environments. Two complementary paper-based activities can be used to support or extend the online learning. The materials are flexible for teacher use; they can be used together in any configuration as a mini-unit or individually to integrate with existing lessons in your subject area. This article describes these supplement materials, suggestions for their implementation, and the results of a field study testing these materials in classrooms.

The Conditions That Support Life online narrated tutorial, one of the interactive animations, introduces three key ingredients—a liquid medium, raw materials in the form of atoms, and an energy source—along with an explanation of how each helps cultivate life on Earth (Figure 1; see Resources). By viewing this piece, students learn the features of Earth that make liquid water possible, how the Earth processes and cycles atoms, and about our planet's energy sources, including plate tectonics, sunlight, and atmospheric processes. Throughout the activity, connections are made to how understanding these ingredients on Earth may help identify other planets and moons where life may exist.

Project the tutorial to the whole class, pausing at areas you wish to highlight or emphasize, asking questions to check for understanding, and making connections to prior knowledge or lessons completed in class. Or you may wish to have students view the piece independently in a computer lab. This 10-minute tutorial requires an active internet connection and includes music and narration; speakers are required if you are projecting it to the class or headphones for independent exploration in the lab. Additional content on the tutorial's web page outlines further considerations in the search for extraterrestrial life and contains a link to NASA's interactive search for habitable planets.

Conditions on other planets are too hostile for life to exist. Or are they? The Life in Extreme Environments interactive, animated map highlights 10 extreme en-

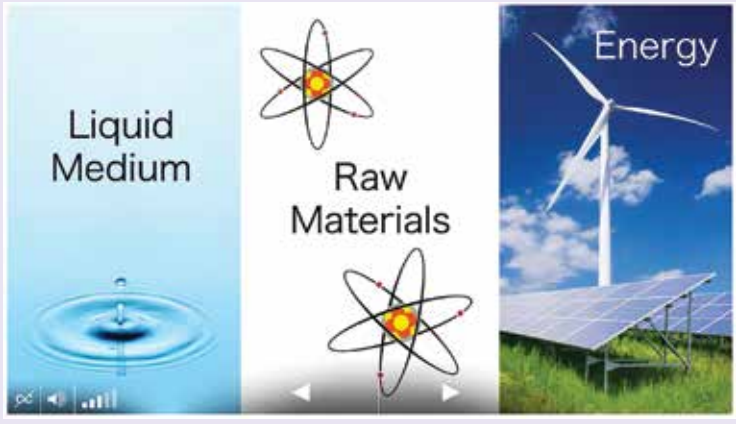
Connections to the *Next Generation Science Standards* (NGSS Lead States 2013)

The Astrobiology curriculum supplement materials align with the *Next Generation Science Standards (NGSS)* in the following ways:

Standard: MS-ESS2 and HS-ESS2: Earth's systems
Disciplinary core ideas
ESS2.A: Earth materials and systems
ESS2.C: The roles of water in Earth's surface processes

Standards: MS-LS4 and HS-LS4: Natural selection and adaptations
Disciplinary core idea
LS4.C: Adaptations
Crosscutting concept
Structure and function

FIGURE 1 Screenshot of the Conditions That Support Life



vironments on Earth where organisms known as *extremophiles* flourish (Figure 2; see Resources). The discovery of these organisms, which thrive despite extremes in conditions such as pH, pressure, temperature, toxins, and UV radiation, gives hope that life may exist on planets and moons with similar conditions. (See "Letters! We Get Letters" in this issue to read a letter from a scientist who has studied extremophiles.)

In a computer lab, have your students explore the map individually, using headphones. As students click on highlighted areas of the map, a pop-up window with a photograph and narrated text opens, providing information about each area, including the challenges to life imposed by the environment, the organisms that live there, and the adaptations that help the organisms survive. Three locations beyond Earth are included in this activity, as well. By exploring this map and the organisms it highlights, students will understand that life can indeed exist in inhospitable places.

A downloadable set of Extremophile Cards can be used in several ways to deepen students' understanding of *adaptations*, or the features of organisms that aid their survival (see Resources). The cards include information about 12 fascinating organisms that thrive in extreme conditions and span all three domains of life (Archaea, Bacteria, and Eukarya). Information about each extremophile is split between two cards with matching illustrations and includes the organism's adaptations, challenges to life, energy source, habitat, and other interesting facts (Figure 3). The cards can be used in conjunction with the Life in Extreme Environments interactive map by asking students to explore the map and select the cards for organisms that could survive in each of the environments. Alternatively, students can sort the cards by different criteria (such as adaptations, challenges to life, or environment) and consider similarities and differences among the organisms in each of their groupings. Students can also shuffle the cards and match the card with the organism's description to the card containing information about the adaptation that allows it to survive (the graphics on both cards should match). These cards can make a great addition to lessons about adaptations.

A fun way to wrap up this exploration of astrobiology is with the downloadable, paper-based *Aterra4* Explorer, a "create-a-creature" activity with an astrobiology twist (see Resources). Working in small groups of 3–4 students or individually, students are

FIGURE 2 Screenshot of the Life in Extreme Environments map

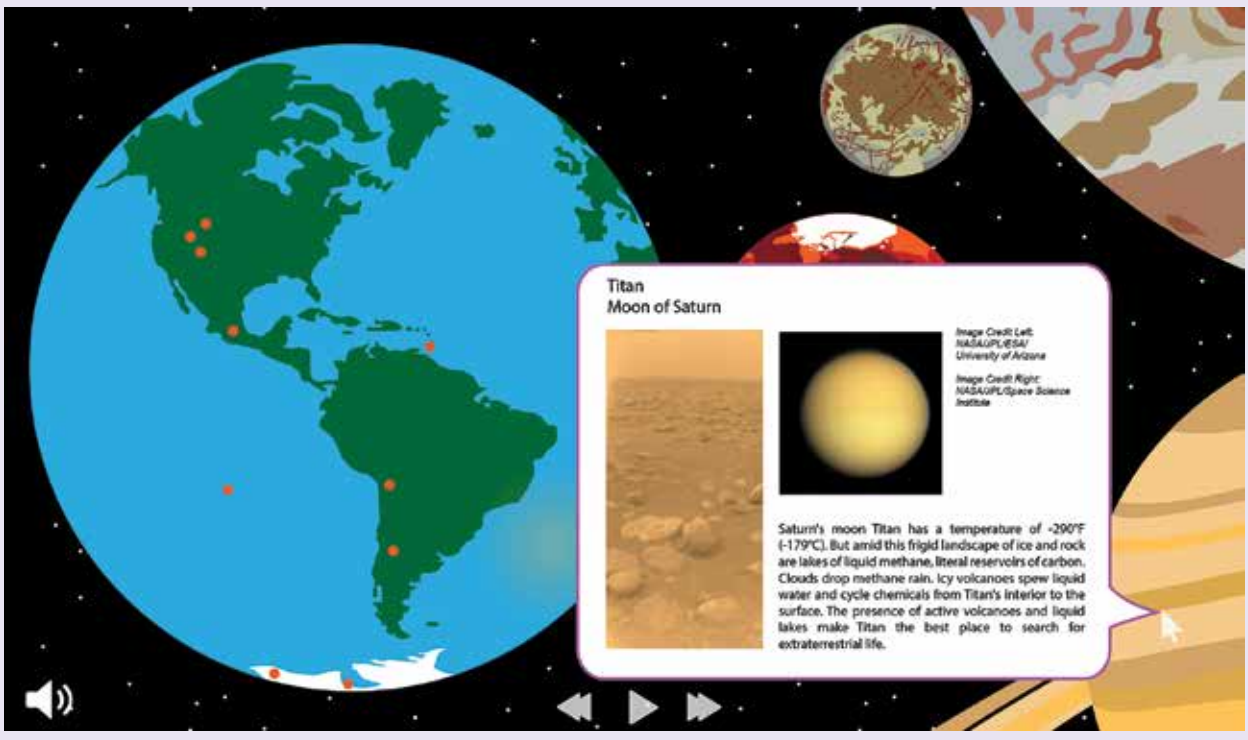
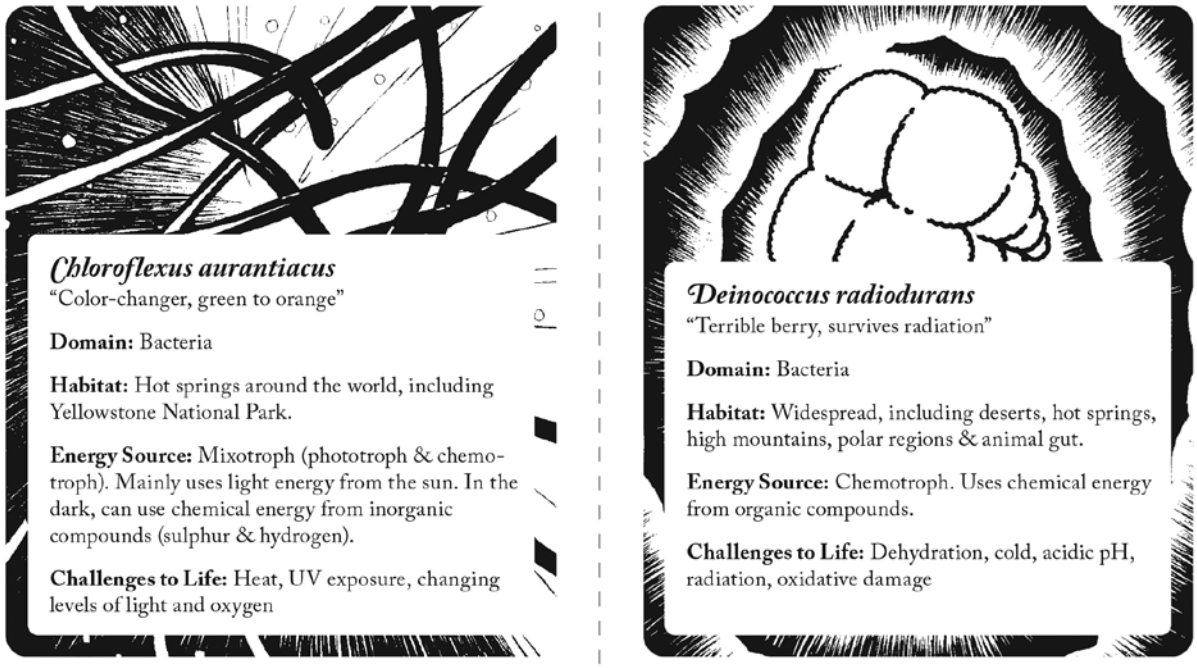


FIGURE 3 Sample Extremophile Cards



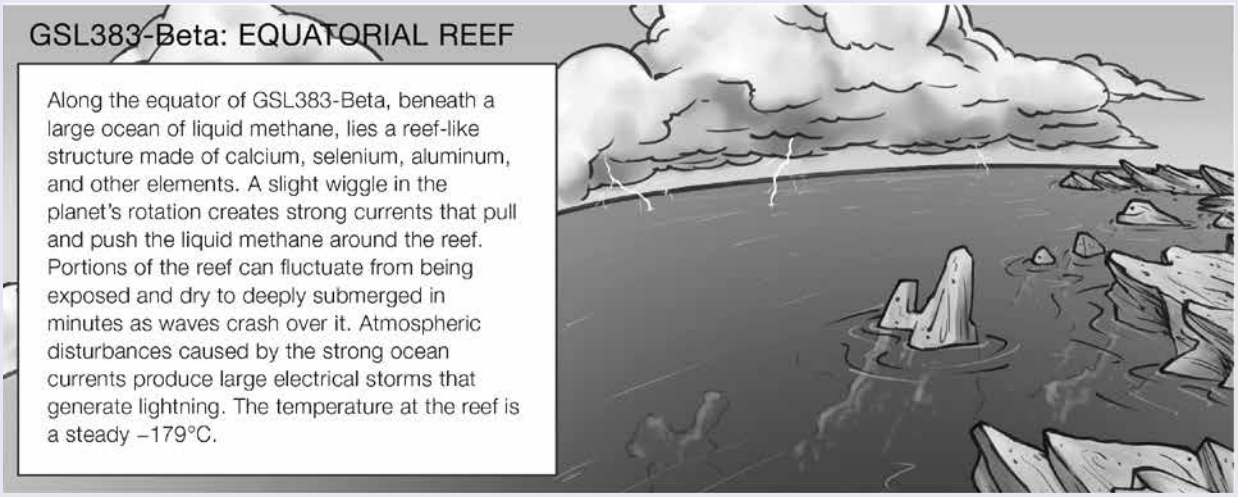
given a description of one of six different, fictional planets, based on data collected by the fictional *Aterra4* deep-space probe (Figure 4). They are tasked with identifying the liquid medium, raw materials, and energy sources that might support life on their given planet; considering any extreme environmental challenges present; and imagining or creating an organism adapted to survive there. The Extremophile Cards described above can also be integrated with this activity; students could read the description of each extremophile on the cards and identify which ones might survive the specific conditions on the given planet.

Field-testing the curriculum

We are in the process of conducting a field test to understand how middle-grade teachers use the Astrobiology materials in the classroom and whether their students' understanding of astrobiology concepts increases between a pretest and a posttest. The results from 1,002 students show that they successfully learned the concepts (as indicated by statistically significant changes in their scores, $p < 0.001$). The assessment items used in the field test are available to download from the Learn.Genetics website (see Resources). The items were developed in a collaboration among five secondary teachers and a science education researcher from the Genetic Science Learning Center. The items were then vetted by three content experts and think-alouds were conducted with eight students, contributing to content and construct test validity.

The preliminary findings from a survey completed by eight integrated-science, Earth-science, biology, or environmental-science teachers show that the educators found the materials easy to incorporate into science lessons. The field-test teachers chose when and how to incorporate the astrobiology lessons into their existing curricula, resulting in a variety of ways the lessons were used. Examples include using the materials as an introduction to what students will learn during the year in an integrated-science course; to link to a plate tectonics unit; to discuss science as a way of thinking; to discuss Earth as part of the solar system; and as a reading/writing assignment. Several teachers reported using the lessons within units on adaptation and the domains of life. Most teachers described their students as very engaged with the materials, while a few indicated their students were somewhat engaged. Most teachers responded that they plan to use the materials again and that they will select activities that

FIGURE 4 A planet description from the *Aterra4* Explorer activity



fit their curriculum and their students' level of understanding rather than use all of the materials.

The teachers assigned their students different methods for matching the Extremophile Cards. One teacher felt that presenting the cards as the starting point for a whole-class conversation, rather than asking students to match on their own, was successful. Another teacher asked groups of students to develop a graphic organizer to demonstrate how they organized the cards. One Earth-science teacher indicated that next year she will leave the pictures off of the cards, as matching the cards by picture was too easy for her students. When asked how they used the *Aterra4* Explorer activity, most teachers said they used it in conjunction with the Extremophile Cards (for example, students used the Extremophile Cards to come up with their own organism for the given planet).

Summary

Used together or as separate activities, the Astrobiology materials will add an exciting new twist to your existing curriculum. As shown in the field-test results, students learn from these materials and teachers find them useful and easy to incorporate. ■

Acknowledgments

The Astrobiology curriculum supplement materials are the product of a collaboration among the Genetic Science Learning Center at the University of Utah, the Great Salt Lake Institute at Westminster College, and 14 secondary science teachers in Utah.

Resources

Aterra4 Explorer—*http://learn.genetics.utah.edu/content/astrobiology/teacher*

Conditions That Support Life online narrated tutorial—*http://learn.genetics.utah.edu/content/astrobiology/conditions*

Extremophile Cards—*http://learn.genetics.utah.edu/content/astrobiology/teacher*

Learn.Genetics—*http://learn.genetics.utah.edu/*

Life in Extreme Environments interactive map—*http://learn.genetics.utah.edu/content/astrobiology/environments*

Reference

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Molly Malone (*molly.malone@utah.edu*) is a senior education specialist at the Genetic Science Learning Center (GSLC) at the University of Utah in Salt Lake City, Utah. ***Dina Drits-Esser*** is the research and evaluation leader at the GSLC. ***Louisa A. Stark*** is the director of the GSLC.