ASTROBIOLOGY IN THE CLASSROOM

by Tim Brennan

Astrobiology is a relatively new field of study in science, one that has found a home in the curriculum of many major universities. It's a multidisciplinary field that draws participants from a range of scientific specialties: geology, physics, chemistry, engineering, computer science, and of course biology and astronomy. At the middle level, it's an exciting mix of topics and questions that can help students see how different fields of science can be integrated. The goal of this article is to define astrobiology and its aims, and to provide some ideas and inspiration for bringing it into a wide range of science classes.

The big questions

During a camp-out in Washington State, I walked back and forth through the campsite as students were buzzing from tent to tent on our first evening out on the class trip. I was ostensibly paying attention to noise levels from these adolescents in an effort to stay on good terms with the friendly retired couple two campsites down.

What I was *really* doing was muttering under my breath about the irony of it all. We'd come out to one of the driest places in the soggy half of our state, and now the stars that we saw so rarely from Seattle were mostly blocked by endless evergreens.

Then I finally found it.

"Hey guys! Come on over! It's important!" I called over to the kids, excited enough to pronounce "Important" with a capital I. They broke off their conversations and made their way over to me in the dark. First I helped them get their unaided eyes oriented, and then I passed around binoculars.

"Take a look in the gap between the trees…over on the side, there's the big tree, and then the small one down and to the right. Can you make out the two stars even with the top of the tree? Follow those stars up and you'll see a little fuzzy patch—that's the Andromeda Galaxy!" The binoculars went up, and the kids who saw it started helping out the others. We then started talking about what we were seeing.

"So they're stars like the Sun?" one of the girls asked.

"Yep."

Pause…

"…and do they all have planets too?"

"A *lot* of them probably do."

Pause…

"So there could be a *lot* of people out there!"

The basic questions of astrobiology are sitting inside all of us. They might be a little less polished at times, but they're things we'd really like to know. Is there life out there? Where would it live? What would it look like? Could we ever find life beyond our planet?

As a physical science teacher, with a background heavy in astronomy, I know it's never hard to get these questions started. If I were a new teacher, they might throw me off guard, as I never intended our discussion to start drifting into talks about *The X-Files* or *E.T.*

As the field of astrobiology has progressed, though, I have been more and more willing to find ways to address these questions more intentionally. They have provided good context for the ideas we've studied, and they've also allowed me

Tim Brennan *is a science teacher at the Northwest School in Seattle, Washington. He welcomes e-mails at* tsbrennan@hotmail.com.

to explore topics outside of the sometimes-isolated realm of my curriculum to make connections with biology, Earth science, and a range of other specialties. This has been an added benefit in my classroom, and has helped my students to think more broadly about what scientists actually *do*.

What is astrobiology?

In the past decade, the interest in the field of astrobiology has been growing, pulling together scientists from a wide range of disciplines—biology, geology, astronomy, chemistry, physics, paleontology, engineering, and others—to begin building a framework for the field. In 2003, NASA arrived at a list of three broad questions that encompass the field of astrobiology:

- How does life begin and evolve?
- Does life exist elsewhere in the universe?
- What is the future of life on Earth and beyond?

This is followed by more than 20 pages of specific goals and objectives that address each of these larger questions. The goals and objectives provide a detailed framework that defines the aims of research in the field of astrobiology (Figure 1). They provide a function similar to what the *Standards* provide to the field of education. Just having students *scan* the *astrobiology.arc.nasa.gov/roadmap/index.html* site is an eye-opener. Students will find that astrobiology covers an astonishing range of disciplines reaching out into the universe. They will also discover that, while the field stretches out into the universe, astrobiology really begins right here on the Earth.

Starting the search here

Astrobiology is always working to get a better picture of how life began on Earth, how it has changed over billions of years, and what major events may have shaped the course of evolution. By understanding these processes on Earth, scientists build a foundation for understanding how life might develop elsewhere in the universe.

Some of the most exciting discoveries have involved the simplest forms of life: bacteria and archaea. Archaea are single-celled organisms similar to bacteria, although fewer than half of their genes are shared with bacteria (for comparison, scientists have found coral that shares 90 percent of its genes with humans!). These bacteria and archea can thrive in extremely hot conditions such as volcanic vents in the ocean, extremely cold conditions such as the ice at the Arctic Circle, and extremely acidic conditions such as volcanic hot springs. Because they thrive in environments we never would have thought livable, these strange organisms are often called *extremophiles*. (Learn more about extremophiles at *www.ucmp.berkeley.edu/archaea/archaea.html*.) These kinds of findings broaden scientists' concept of where life could exist elsewhere in the universe. We can expand our search to more extreme environments where we may not have looked before.

Places to live in the universe

Scientists have broadened our search for life in our own solar system, beginning with an examination of the extreme environments of our own planet. Scientists have also turned their attention toward the exploration of other places in the solar system where water could be, or once could have been found in a liquid state. Scientists believe that the presence of liquid water is the single most important requirement for life, as we know it, to exist (although it's possible that other chemical environments, such as ammonia, could harbor life too). Mars, of course, has been the recent target of this search, with news coming back daily from the Mars Exploration Rovers. Another candidate is Europa, one of Jupiter's four largest moons, which may be hiding huge oceans of water beneath its icy surface.

The next step is to search outside our solar system for planets similar to Mars and Europa. Given the great distances involved, however, where do we start? Astronomers have been using the increasingly greater precision of today's instruments to search for signs of planets around other stars in our galaxy. In 1995, the first extra-solar planet was detected around a star in the constellation

FIGURE 1 **Main goals of NASA's astrobiology framework**

Goal 1: Understand the nature and distribution of habitable environments in the universe

Goal 2: Explore for past or present habitable environments, pre-biotic chemistry, and signs of life elsewhere in our solar system

Goal 3: Understand how life emerges from cosmic and planetary precursors

Goal 4: Understand how past life on Earth interacted with its changing planetary and solar-system environment

Goal 5: Understand the evolutionary mechanisms and environmental limits of life

Goal 6: Understand the principles that will shape the future of life, both on Earth and beyond

Goal 7: Determine how to recognize signatures of life on other worlds and on early Earth

Pegasus. Scientists were able to detect the planet, which is about half the mass of Jupiter, because it created a gravitational pull on its parent star as it went around in its four-day orbit. While this planet is almost certainly too hot to imagine even the strangest life calling it "home," over a hundred planets have since been found, and the number continues to grow each year.

Are we alone?

Not all scientists agree on what constitutes a reasonable environment to support life. In fact, because astrobiology is at the leading edge of scientific research, there are many areas of research that provide fertile ground for scientific debate. As advances in science and technology continue, there will be new discoveries that will extend our understanding of the origins, potential, and future of life in the universe.

It's a good thing when students can see areas of science where well-informed scientists can have very different opinions. Astrobiology has been a fertile field for this kind of debate. Some scientists believe that we will inevitably be able to contact complex life—as long as we continue the search. The words from my student at the campsite get right to the heart of their reasoning, sometimes called the Big Number Theory: The universe contains so many stars, and so many worlds around those stars, that complex life must be out there, even if it evolved around a tiny percentage of the stars.

On the other end of things, there are scientists who, through a careful look at what life needs, and what the universe has to offer, expect complex life to be a rare thing. The most restrictive conditions they point to are the need for liquid water and time for life to evolve. While there might be a *lot* of bacteria out there, we might be hard pressed to find anything much more complex than that. The fact that we have not really even begun to be able to answer these questions puts astrobiology at the forefront of scientific research.

Astrobiology in the classroom

The cutting edge of science is a fun and challenging place to go as a science teacher. I feel like I'm doing the right thing when I help students to realize that science is alive, and that there are many questions left unanswered. At the same time, I sometimes feel ill equipped to bring new ideas into the classroom, either due to a lack of expertise, or to a lack of tested and reliable activities. To incorporate astrobiology into your curriculum, refer to the following:

1. Included in this magazine is a 12-page pullout developed at the Pacific Science Center in Seattle that provides activities you may be able to incorporate into your current curriculum. This Activity Guide is part of the educational-outreach materials that enrich the NOVA Origins four-part TV series airing in late September 2004. Other *Origins*-related activities can be found at the NOVA website, *www.pbs.org/nova/origins*, and at the Pacific Science Center website, *www.pacsci.org/origins*.
2. The following resources will help you and your students explore the realm of astrobiology on your own:

- The National Astrobiology Institute's home page—*nai.arc.nasa.gov*. This includes articles on current research in astrobiology, as well as suggested books and other resources for teachers and students.
- Astrobiology Magazine online—*www.astrobio.net/news/index.php*. Features articles about climate history, extreme forms of life on Earth, the search for life on Mars, discoveries of new planets, stellar evolution, and more. It also has a nice glossary of terms and links to several sister sites.
- Introduction to the Archaea—*www.ucmp.berkeley.edu/archaea/archaea.html*. This is an online source from U.C. Berkeley that offers an excellent introduction to extremophiles.
- The Encyclopedia of Astrobiology, Astronomy, and Spaceflight—*www.daviddarling.info/encyclopedia/ETEmain.html*. This is an excellent place to find out more about a specific topic from the astronomical end of things.
- The Extrasolar Planets Encyclopedia—*www.obspm.fr/encycl/encycl.html*.
- *Gravity simulator—www.arachnoid.com/gravitation*. This is a site that has a gravity simulator for making your own solar systems and "playing" with gravity.

3. Finally, even as you are reading this article, hundreds of scientists, computer programmers, and engineers are exploring the field of astrobiology. Many who started their careers in separate disciplines have recently come together to work on projects in universities and, of course, at NASA. Here are links to some of the current and future missions that are helping us explore the solar system for life and signs of life:

- NASA's astrobiology mission site—*astrobiology.arc.nasa.gov/missions/index.cfm*
- Mars Global Surveyor—*mpfwww.jpl.nasa.gov/mgs*
- Mars Exploration Rovers—*mars.jpl.nasa.gov/mer*
- Galileo Europa missions—*www2.jpl.nasa.gov/galileo/gem/fact.html*
- Jupiter Icy Moons Orbiter—*www.jpl.nasa.gov/jimo/mission.cfm*