30.E: Life in the Universe (Exercises)

For Further Exploration

Articles

Astrobiology

Chyba, C. “The New Search for Life in the Universe.” *Astronomy* (May 2010): 34. An overview of astrobiology and the search for life out there in general, with a brief discussion of the search for intelligence.

Dorminey, B. “A New Way to Search for Life in Space.” *Astronomy* (June 2014): 44. Finding evidence of photosynthesis on other worlds.

McKay, C., & Garcia, V. “How to Search for Life on Mars.” *Scientific American* (June 2014): 44–49. Experiments future probes could perform.

Reed, N. “Why We Haven’t Found Another Earth Yet.” *Astronomy* (February 2016): 25. On the search for smaller earthlike planets in their star’s habitable zones, and where we stand.

Shapiro, R. “A Simpler Origin of Life.” *Scientific American* (June 2007): 46. New ideas about what kind of molecules formed first so life could begin.

Simpson, S. “Questioning the Oldest Signs of Life.” *Scientific American* (April 2003): 70. On the difficulty of interpreting biosignatures in rocks and the implications for the search for life on other worlds.

SETI

Chandler, D. “The New Search for Alien Intelligence.” *Astronomy* (September 2013): 28. Review of various ways of finding other civilizations out there, not just radio wave searches.

Crawford, I. “Where Are They?” *Scientific American* (July 2000): 38. On the Fermi paradox and its resolutions, and on galactic colonization models.

Folger, T. “Contact: The Day After.” *Scientific American* (January 2011): 40–45. Journalist reports on efforts to prepare for ET signals; protocols and plans for interpreting messages; and discussions of active SETI.

Kuhn, J., et al. “How to Find ET with Infrared Light.” *Astronomy* (June 2013): 30. On tracking alien civilizations by the heat they put out.

Lubick, N. “An Ear to the Stars.” *Scientific American* (November 2002): 42. Profile of SETI researcher Jill Tarter.

Nadis, S. “How Many Civilizations Lurk in the Cosmos?” *Astronomy* (April 2010): 24. New estimates for the terms in the Drake equation.

Shostak, S. “Closing in on E.T.” *Sky & Telescope* (November 2010): 22. Nice summary of current and proposed efforts to search for intelligent life out there.

Websites

Astrobiology

Astrobiology Web: http://astrobiology.com/. A news site with good information and lots of material.

Exploring Life’s Origins: http://exploringorigins.org/index.html. A website for the Exploring Origins Project, part of the multimedia exhibit of the Boston Museum of Science. Explore the origin of life on Earth with an interactive timeline, gain a deeper knowledge of the role of RNA, “build” a cell, and explore links to learn more about astrobiology and other related information.

History of Astrobiology: https://astrobiology.nasa.gov/about/...-astrobiology/. By Marc Kaufman, on the NASA Astrobiology site.

Life, Here and Beyond: https://astrobiology.nasa.gov/about/. By Marc Kaufman, on the NASA Astrobiology site.

SETI

Berkeley SETI Research Center: https://seti.berkeley.edu/. The University of California group has received a $100 million grant from a Russian-American billionaire to begin the Breakthrough: Listen project, a major step forward in the number of stars and number of radio channels being searched.

Fermi Paradox: http://www.seti.org/seti-institute/p.../fermi-paradox. Could we be alone in our part of the Galaxy or, more dramatic still, could we be the only technological society in the universe? A useful discussion.

Planetary Society: www.planetary.org/explore/projects/seti/. This advocacy group for exploration has several pages devoted to the search for life.

SETI Institute: http://www.seti.org. A key organization in the search for life in the universe; the institute's website is full of information and videos about both astrobiology and SETI.

SETI: http://www.skyandtelescope.com/tag/seti/. *Sky & Telescope* magazine offers good articles on this topic.

Videos

Astrobiology

Copernicus Complex: Are We Special in the Cosmos?: https://www.youtube.com/watch?v=ERp0AHYRm_Q. A video of a popular-level talk by Caleb Scharf of Columbia University (1:18:54).

Life at the Edge: Life in Extreme Environments on Earth and the Search for Life in the Universe: https://www.youtube.com/watch?v=91JQmTn0SF0. A video of a 2009 nontechnical lecture by Lynn Rothschild of NASA Ames Research Center (1:31:21).

Saturn's Moon Titan: A World with Rivers, Lakes, and Possibly Even Life: https://www.youtube.com/watch?v=bbkTJeHoOKY. A video of a 2011 talk by Chris McKay of NASA Ames Research Center (1:23:33).

SETI

Allen Telescope Array: The Newest Pitchfork for Exploring the Cosmic Haystack: https://www.youtube.com/watch?v=aqsI1HZCgUM. A 2013 popular-level lecture by Jill Tarter of the SETI Institute (1:45:55).

Confessions of an Alien Hunter: fora.tv/2009/03/31/Seth_Shost...n_Alien_Hunter. 2009 interview with Seth Shostak on FORA TV (36:27).

Search for Extra-Terrestrial Intelligence: Necessarily a Long-Term Strategy: http://www.longnow.org/seminars/0200...term-strategy/. 2004 talk by Jill Tarter at the Long Now Foundation (1:21:13).

Search for Intelligent Life Among the Stars: New Strategies: https://www.youtube.com/watch?v=m9WxW2ktcKU. A 2010 nontechnical talk by Seth Shostak of the SETI Institute (1:29:58).

Collaborative Group Activities

1. If one of the rocks from Mars examined by a future mission to the red planet does turn out to have unambiguous signs of ancient life that formed on Mars, what does your group think would be the implications of such a discovery for science and for our view of life elsewhere? Would such a discovery have any long-term effects on your own thinking?
2. Suppose we receive a message from an intelligent civilization around another star. What does your group think the implications of this discovery would be? How would your own thinking or personal philsophy be affected by such a discovery?
3. A radio message has been received from a civilization around a star 40 light-years away, which contains (in pictures) quite a bit of information about the beings that sent the message. The president of the United States has appointed your group a high-level commission to advise whether humanity should answer the message (which was not particularly directed at us, but comes from a beacon that, like a lighthouse, sweeps out a circle in space). How would you advise the president? Does your group agree on your answer or do you also have a minority view to present?
4. If there is no evidence that UFOs are extraterrestrial visitors, why does your group think that television shows, newspapers, and movies spend so much time and effort publicizing the point of view that UFOs are craft from other worlds? Make a list of reasons. Who stands to gain by exaggerating stories of unknown lights in the sky or simply fabricating stories that alien visitors are already here?
5. Does your group think scientists should simply ignore all the media publicity about UFOs or should they try to respond? If so, how should they respond? Does everyone in the group agree?
6. Suppose your group is the team planning to select the most important sights and sounds of Earth to record and put on board the next interstellar spacecraft. What pictures (or videos) and sounds would you include to represent our planet to another civilization?
7. Let's suppose Earth civilization has decided to broadcast a message announcing our existence to other possible civilizations among the stars. Your group is part of a large task force of scientists, communications specialists, and people from the

humanities charged with deciding the form and content of our message. What would you recommend? Make a list of ideas.
8. Think of examples of contact with aliens you have seen in movies and on TV. Discuss with your group how realistic these have been, given what you have learned in this class. Was the contact in person (through traveling) or using messages? Why do you think Hollywood does so many shows and films that are not based on our scientific understanding of the universe?
9. Go through the Drake equation with your group and decide on values for each factor in the estimate. (If you disagree on what a factor should be within the group, you can have a "minority report.") Based on the factors, how many intelligent, communicating civilizations do you estimate to be thriving in our Galaxy right now?

Review Questions

1. What is the Copernican principle? Make a list of scientific discoveries that confirm it.
2. Where in the solar system (and beyond) have scientists found evidence of organic molecules?
3. Give a short history of the atoms that are now in your little finger, going back to the beginning of the universe.
4. What is a biomarker? Give some possible examples of biomarkers we might look for beyond the solar system.
5. Why are Mars and Europa the top targets for the study of astrobiology?
6. Why is traveling between the stars (by creatures like us) difficult?
7. What are the advantages to using radio waves for communication between civilizations that live around different stars? List as many as you can.
8. What is the "cosmic haystack problem"? List as many of its components as you can think of.
9. What is a habitable zone?
10. Why is the simultaneous detection of methane and oxygen in an atmosphere a good indication of the existence of a biosphere on that planet?
11. What are two characteristic properties of life that distinguish it from nonliving things?
12. What are the three requirements that scientists believe an environment needs to supply life with in order to be considered habitable?
13. Can you name five environmental conditions that, in their extremes, microbial life has been challenged by and has learned to survive on Earth?

Thought Questions

1. Would a human have been possible during the first generation of stars that formed right after the Big Bang? Why or why not?
2. If we do find life on Mars, what might be some ways to check whether it formed separately from Earth life, or whether exchanges of material between the two planets meant that the two forms of life have a common origin?
3. What kind of evidence do you think would convince astronomers that an extraterrestrial spacecraft has landed on Earth?
4. What are some reasons that more advanced civilizations might want to send out messages to other star systems?
5. What are some answers to the Fermi paradox? Can you think of some that are not discussed in this chapter?
6. Why is there so little evidence of Earth's earliest history and therefore the period when life first began on our planet?
7. Why was the development of photosynthesis a major milestone in the evolution of life?
8. Does all life on Earth require sunshine?
9. Why is life unlikely to be found on the surface of Mars today?
10. In this chapter, we identify these characteristic properties of life: life extracts energy from its environment, and has a means of encoding and replicating information in order to make faithful copies of itself. Does this definition fully capture what we think of as "life"? How might our definition be biased by our terrestrial environment?
11. Given that no sunlight can penetrate Europa's ice shell, what would be the type of energy that could make some form of europan life possible?
12. Why is Saturn's moon Enceladus such an exciting place to send a mission?
13. In addition to an atmosphere dominated by nitrogen, how else is Saturn's moon Titan similar to Earth?
14. How can a planet's atmosphere affect the width of the habitable zone in its planetary system?
15. Why are we limited to finding life on planets orbiting other stars to situations where the biosphere has created planet-scale changes?

Figuring for Yourself

1. Suppose astronomers discover a radio message from a civilization whose planet orbits a star 35 light-years away. Their message encourages us to send a radio answer, which we decide to do. Suppose our governing bodies take 2 years to decide whether and

how to answer. When our answer arrives there, their governing bodies also take two of our years to frame an answer to us. How long after we get their first message can we hope to get their reply to ours? (A question for further thinking: Once communication gets going, should we continue to wait for a reply before we send the next message?)

2. The light a planet receives from the Sun (per square meter of planet surface) decreases with the square of the distance from the Sun. So a planet that is twice as far from the Sun as Earth receives $(1/2)^2 = 0.25$ times (25%) as much light and a planet that is three times as far from the Sun receives $(1/3)^2 = 0.11$ times (11%) as much light. How much light is received by the moons of Jupiter and Saturn (compared to Earth), worlds which orbit 5.2 and 9.5 times farther from the Sun than Earth?
3. Think of our Milky Way Galaxy as a flat disk of diameter 100,000 light-years. Suppose we are one of 1000 civilizations, randomly distributed through the disk, interested in communicating via radio waves. How far away would the nearest such civilization be from us (on average)?
