Life Beyond Earth Suggested Resources

Institutions and Websites

The Planetary Society. 85 S. Grand Ave., Pasadena, CA91105-1602 Tel: 626-793-5100 email: tps@planetary.org web: planetary.org Publishes *The Planetary Report* quarterly. Mission: to further space exploration. Maintains the Bruce Murray Space Imagery Library.

The SETI Institute. www.seti.org 189 Bernardo Ave., Suite 100, Mountainview, CA 94043 Conducts SETI research from grants and contributions. No government money, because in 1993 Sen Richard Bryan (D-NV) thought that looking for other intelligence in the cosmos was silly and a waste of several million $/year.

www.exoplanets.co/exoplanets-websites.html A LARGE listing of websites that deal with exoplanets, catalogs, current and planned missions, etc., obviously a growth industry.

www.exoplanet.eu Another of many catalogs.

http://www.exoplanets.org Catalogs what is known about exoplanets (but did not have the 715 recent additions when I visited March 15); you can print listings, make plots of different parameters, etc.

www.openexoplanetcatalogue.com Catalog of all discovered exoplanets (but updated how diligently). The database can be accessed directly (I'm told), don't need website.

Habitable Planets Catalog

CoRoT (Convection, Rotation and Transit) mission pages Planet finder and characterizer 2006 European mission

Kepler Mission pages

TESS (Transiting Exoplanet Survey Satellite) mission pages – NASA project

CHEOPS (CHaracterizing ExOPlanet Satellite) mission pages – ESA project

Astrobiology and Life's Origins

Astrobiology journal

Crockett, C. 2014. Exoplanet oxygen may not signal life. *Science News* 185(8): 11. Summary of a paper by Robin Wordsworth and Raymond Pierrehumbert published in *Astrophysical J. Letters*, postulating a scenario for establishing a stable oxygenated atmosphere. Whether the postulated special circumstances would ever apply to an Earth-type planet (such as not having nitrogen in the atmosphere) is debatable.

de Duve, C. 1991. *Blueprint for a Cell: The Nature and Origin of Life*. Burlington, NC: Neil Patterson Publishers, Carolina Biological Supply Co.

de Duve, C. 1995. The beginnings of life on Earth: Life arose naturally through a long succession of chemical steps that were bound to take place under the conditions that prevailed on Earth four billion years ago. *American Scientist* 83(5): 428-437. Title says it all; does not mean complex life is inevitable, though. See Ward and Webb below under SETI grouping.

de Duve, C. 1995. *Vital Dust: Life as a Cosmic Imperative*. New York: Basic Books.

Deamer, D.W. and Fleischaker, G.L., eds. 1994. *Origins of Life: The Central Concepts*. Boston: Jones and Bartlett. Given certain conditions, is life inevitable?

Exploring Martian Habitability. 2014. Introduction and abstracts of seven papers. *Science* 343(6169): 386-387. One paper is about the Opportunity rover at Endeavour crater, the other six are about the Curiosity rover at Gale crater. Full text: www.sciencemag.org/extra/curiosity

Impey, C., Lunine, J., Funes, J. 2012. *Frontiers of Astrobiology*. York: Cambridge U. Press. 331p. ISBN 978-1-107-00641-6 Leading international experts explore the frontiers of astrobiology, investigating the very latest research questions. Where are the most likely sites for life in the Solar System? What are the best strategies for detecting intelligent extraterrestrial life?

Miller, S.L. 1953. A production of amino acids under possible primitive Earth conditions. *Science* 117: 528-529. The first real experiment on formation of life. Electrical discharges (simulating lightning) created some of the building blocks of life from an atmosphere of hydrogen, methane, ammonia, etc.

Nadis, S. 2014, March. Alien worlds on Earth: Astrobiologist Chris McKay searches extreme landscapes for clues about life on other planets. *Discover* [no volume no.] p. 40-45. Namib Desert, volcano that erupts carbonate lava, etc.

Ralph, J. 2012. Did life change Earth's geology? *Astronomy* 40(11): 44-49. Introduction of free oxygen into atmosphere by photosynthetic life created a wide range of minerals.

Rothery, D.A., Gilmour, I., Sephton, M.A. 2011. *An Introduction to Astrobiology, second edition*. 2011. New York: Cambridge U. Press. 360p. ISBN 978-1-107-60093-5 "Providing and introduction to the origin of life, the habitable environments in our solar system and the search for exoplanets, this new edition has been updated to take in the latest developments."

Schopf, J.W. 1992. The oldest fossils and what they mean. In *Major Events in the History of Life*, ed. J.W. Schopf. Boston: Jones and Bartlett. p. 29-63.

Schopf, J.W. 1993. Microfossils of the early Archaean apex chert: new evidence of the antiquity of life. *Science* 260: 640-646. Life appeared very early in Earth history, before 3.55 bya,

possibly before the Late Heavy Bombardment (LHB; ~4.0 to 3.8 bya) although de Duve assumes the LHB would have made life impossible.

Waltham, D. 2014. *Lucky Planet: Why Earth is Exceptional -- and What that Means for Life in the Universe*. New York: Basic Books. 198 p. ISBN 978-0-465-03999-9 (hc), 978-0-465-08082-3 (e-bk) Makes the case that Earth enjoys a privileged place in the cosmos because it is exceptionally stable and has an exceptionally stable star, which has enabled complex life to develop and persist. If this thesis is true, complex life must be rare because the "exceptionally stable" Earth has seen at least five great extinctions. One, at the end of the Permian, wiped out more than 90% of all species existing on land in and the oceans at that time.

SETI (Search for Extraterrestrial Intelligence) and the Search for Life

Coustenis, A., Encrenaz, T. 2013. *Life Beyond Earth: The Search for Habitable Worlds in the Universe*. New York: Cambridge U. Press. 320p. ISBN 978-1-107-02617-9 "Two leading astrophysicists provide an engaging account of our quest for habitable environments. Starting from basic concepts, they recount fascinating recent discoveries and provide insight into future space missions."

Shellans, M.H. 2014. The probability and nature of an interstellar information-trading community. *Analog Science Fiction and Fact* 134(3): 29-37. Explores what would be required to set up an interstellar communications network and finds it surprisingly doable in our neighborhood (radius of 20 light years) with current laser technology.

Shostak, S. 2009. *Confessions of an Alien Hunter: A Scientist's Search for Extraterrestrial Intelligence*. Washington, DC: National Geographic Society. 309 p. An entertaining look at the SETI idea, history and community, along with problems and current status.

Exoplanets

Billings, L. 2014. The search for life on faraway moons. *Scientific American* 310(1): 38-43. "Moons orbiting distant exoplanets may account for most of the habitable locales in the galaxy, if only we could find them."

Clery, D. 2014. Rival detectors prepare to take snapshots of distant worlds. *Science* 243: 833. N. American and European scientists image exoplanets directly with Earth-based telescopes. Works best for large planets far from their stars because the star's light must be avoided in order to see the orders of magnitude dimmer planets. Still, it's a valuable supplement to other detection methods. Imaging of Earth-type planets will require a space-based telescope.

de Wit, J. , Seager, S. 2013. Constraining exoplanet mass from transmission spectroscopy. *Science 342(6165): 1473-1477*. Dec. 20. Explanation of method of determining the mass of a planet by determining the density profile of its atmosphere. This is important because the transit detection method gives a good estimate of the size of a planet, but not its mass. The mass and size together show if the planet is Earth-like or not and the additional information about its atmosphere will eventually tell us about habitability.

Ferris, T. 2009. Worlds apart. *National Geographic* 216(6): 78-93. Search for exoplanets, methods, early findings.

Huber, D., Carter, J.A., Barbieri, M. et al. 2013. Stellar spin-orbit misalignment in a multiplanet system. *Science* 342(6156): 331-334. Oct. 18. More weirdness in extraterrestrial planetary systems.

Johnson, J.A. 2014. Warm planets orbiting cool stars. *Physics Today* 67(3): 31-36. Red dwarfs are the most common type of star in the galaxy and this paper explores the search for habitable planets around them, and some more general criteria applicable to all stars.

Kipping, D.M., et al. 2012. The hunt for exomoons with Kepler (HEK): I. Description of a new observational project. *Astrophysical J*. 750(2): 115-134.
http://arxiv.org/abs/1201.0752 referenced in Billings' article above.

Kruesi, L. 2014. The next search for Earth-like worlds. *Astronomy* 42(4): 44-49. A fast review of what has been found (not including the 715 confirmed exoplanets added at the end of February 2014) and a look at the revised Kepler mission, and the European Space Agency and NASA follow-on missions.

Lammer, H., Blanc, M., Benz, W. et al. 2013. The science of exoplanets and their systems. *Astrobiology* 13(9): 793-813. DOI: 10.1089/ast.2013.0997 An excellent survey of what we know about exoplanets, including how we find them, and what the future holds for the search for other worlds.

Lerner, E.M. 2013. Alien worlds: Not in Kansas anymore. *Analog Science Fiction and Fact* 133(10): 23-32. Looks at how exoplanets might vary from the familiar (gravity, moons, day length, seasons, climate, multiple stars, etc.), touches on engineering to change some of those things in direction of habitability for us.

Powell, C.S. 2013, December. Meet the new planet hunters. *Discover Magazine* (no volume no.), p. 60-61. Info about the follow-on to Kepler, TESS, a survey satellite designed to find planets that the new telescopes can study in detail.

S.S. 2014. Planets weighed by starlight. *Astronomy* 42(4): 22. Explanation of new method of determining a planet's mass by measuring the density profile of its atmosphere as it transits its star, discovered by Julien de Wit and Sara Seager (above).

Talcott, R. 2013. Top 10 exoplanets. *Astonomy* 41(10): 22-27. An examination of the extreme variety of discoveries. Unfortunately, a second Earth is not one of the extremes.

Taylor, S.R. 2012. *Destiny or Chance Revisited: Planets and their Place in the Cosmos*. New York: Cambridge U. Press. 313p. ISBN 978-1-107-01675-0 Current knowledge of exoplanets and the search for another Earth-like planet. Detailed studies of Earth and our Solar System as a basis for understanding exoplanets and planetary habitability.

General Planetary Science

de Pater, I., Lissauer, J.J. 2010. *Planetary Sciences, second edition*. New York: Cambridge U. Press. 689p. ISBN 978-0-521-85371-2 Authoritative introduction for physical sciences grad students.

Drake, N. 2012. Rock, rattle and roll, planetary scientists seek to fill in gaps in outer solar system's formative years. *Science News* 181(9): 24-28. Good look at formation of gas and ice giants, including effects on inner solar system.

Eicher, D.J. 2013. *Comets!: Visitors from Deep Space*. New York: Cambridge U. Press. 250p. ISBN 978-1-107-62277-7 History, present and future of these visitors from the Kuiper Belt and Oort Cloud, science of behavior and how to observe and photograph them.

Encrenaz, T. 2014. *Planets Ours and Others: From Earth to Exoplanets*. Hackemack, NJ: World Scientific Publishing Co. Ltd. 187 p. Excellent introduction to planetary science, emphasis on atmospheres. Translation from the French, the author is a senior scientist in the French space agency, she specializes in the atmospheric end of planetology, and she knows her stuff. Really up to date, but not too much on exoplanets, mostly on the solar system. ISBN 978-9814525152

Freudenreich, H. 1999. Deconstructing the Milky Way: Astronomers Know More About Distant Galaxies than they Do About Our Own Milky Way. *American Scientist* 87(5): 418-427. Not strictly on SETI or exoplanets, but shows how we are finding out about the structure of the Milky Way, something surprisingly difficult.

Irion, R. 2013. It all began in chaos. *National Geographic* 224(1): 42-59. A good explanation of the evolution of the solar system according to the Nice (city in southern France) model .

Kruesi, L. 2012. When Earth felt cosmic rain. *Astonomy* 40(11): 30-35. Late Heavy Bombardment (4 to 3.8 Gya)

Lang, K.R. 2011. *The Cambridge Guide to the Solar System*. New York: Cambridge U. Press. 502p. ISBN 978-0-521-19857-8 Richly illustrated with full color images, this reference provides and up-to-date description of the planets, their moons, and recent exoplanet discoveries. Appropriate for high school and undergraduates.

Lissauer, J.J., de Pater, I. 2013. *Fundamental Planetary Science: Physics, Chemistry and Habitability*. New York: Cambridge U. Press. 450p. ISBN 978-0-521-61855-7 "Á quantitative introduction to the Solar System and planetary systems science for advanced undergraduate students, this engaging new textbook explains the wide variety of physical, chemical and geological processes that govern the motions and properties of planets, and how these processes affect the development of life."

McSween, H.Y., Jr. 2010. *Cosmochemistry*. New York: Cambridge U. Press. 568p. ISBN 978-0-521-87862-3 "Provides the first interdisciplinary introduction to cosmochemistry, making it

accessible to undergraduates and graduate students from a range of backgrounds. Boxes give key definitions and minicourses in mineralogy, chemistry, and other essential background information."

Melosh, H.J. 2011. *Planetary Surface Processes*. New York: Cambridge U. Press. 520p. ISBN 978-0-521-51418-7 Comprehensive advanced text on processes affecting planetary surfaces. Employs quantitative approach.

Talcott, R. 2012. How the solar system came to be. *Astronomy* 40(11): 24-29. Exoplanets, too

Specific Planets and Satellites

Müller-Wodarg, I, Griffith, C.A., Lellouch, E., Cravens, T.E. 2013. *Titan*. York: Cambridge U. Press. 404p. ISBN 978-0-521-19992-6 "This comprehensive reference examines the physical processes that shape the fascinating atmospheric structure and chemistry, weather, climate, circulation and surface geology of Titan, Saturn's largest moon. The text also surveys leading theories about Titan's origin and evolution, and assesses their implications for understanding the formation of other complex planetary bodies.

Ozima, M., Korenaga, J., Yin, Qing-Zhu. 2012. *The Earth: Its Birth and Growth, second edition*. New York: Cambridge U. Press. 164p. ISBN 978-1-107-60076-8 "This rigorous but accessible second edition explores Earth's evolution over 4.6 billion years, explaining the underlying physical and chemical principles without heavy mathematics."

Over the years there have been books by individual authors and symposia by multiple investigators on most of the individual planets in the solar system, see solar system handout for some of them. Also, search the planet's name in *Wikipedia* and look at the references in the *Wikipedia* entry.

Society and Cultural Factors

Billingham, J., Heyns, R., Milne, D., Doyle, S., Klein, M., Heilbron, J. Ashkenaz, M., Michaud, M. and Lutz, J. 1999. *Social Implications of the Detection of Extraterrestrial Civilization: A Report on the Workshops on the Cultural Aspects of SETI Held in October 1991, May 1992 and September 1992 at Santa Cruz, California*. Santa Cruz, CA: SETI Press. ISBN 0966633504 Out of print: Synopsis at the SETI Institute website suggests that there would be no significant panic, dismay or unrest.

Diamond, J. 2005. *Collapse: How Societies Choose to Fail or Succeed*. New York: Viking Press. 575 p. Many factors determine whether societies succeed or fail, but the primary one is their knowledge and attitude toward environmental problems. We face an environmental problem due to the accumulation of greenhouse gases in our atmosphere that could easily result in catastrophic sea level rise and the loss of quadrillions of dollars of coastal infrastructure and some of the world's largest cities. We know how to solve the problem but lack the political will to do so. The primary cause is corporate greed accruing to a few very wealthy individuals who believe they can insulate themselves from the consequences and care nothing for others.

Interstellar Colonization

Andrews, Arlen, Sr. 2013. Homesteading to the stars: Colony vs. crew. *Analog Science Fiction*

and Fact 133(12): 49-55. Envisions a fleet of asteroids with propulsion, assumes that any journey will take multiple generations and proposes ways to keep the crew/colonists gainfully occupied and motivated (not to mention sane).

Benningfield, D. Dec 2013/Jan 2014. Interstellar. *Air & Space* 28(6): 48-51. Engineering problems alone seem to say that it will be a long time, plus what about the human side? Pessimistic

Mallove, E., Matloff, G. 1989. *The Starflight Handbook: A Pioneer's Guide to Interstellar Travel*. New York: John Wiley & Sons. 274p. ISBN 0-471-61912-4 A fascinating compendium of ideas about accomplishing interstellar travel that proves people have been seriously considering the problem for some time. Whether any of the approaches are practical or will ever be tried is another question entirely. We apparently lack the will to colonize the solar system at present, although it is technologically feasible.