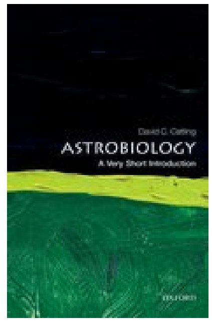
Astrobiology: pouring cold asteroid water on Aristotle



Astrobiology: A Very Short Introduction

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By David C. Catling

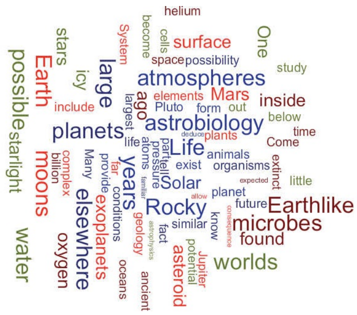
Over 2,300 years ago, in his book *De Caelo* (*On the Heavens*), Aristotle asked if other Earth-like worlds existed and dismissed the idea. But now, remarkably, the question is on the verge of being answered scientifically. NASA's *Kepler space telescope* (http://www.nasa.gov/mission_pages/kepler/main/index.html), launched in 2009, has collected data on the statistical occurrence of small planets that orbit stars at a distance where it's the right temperature for liquid water and conceivably life. The endeavour of identifying potentially habitable planets is part of the convergence of astronomy, biology and geology into *astrobiology*—the study of the origin and evolution of life on our own planet and the possible variety of life elsewhere.

(https://42796r1ctbz645bo223zkcdl-wpengine.netdna-ssl.com/wp-content/uploads/2013/10/astro2.jpg)In astrobiology, the need to assimilate different disciplines is illustrated by the factors that allow Earth-like planets to form. Someone familiar with astrophysics and geology can deduce that rocky planets are an expected consequence of the physics of starlight. Meanwhile, a scientist who knows planetary science and geochemistry will conclude that you drink asteroid water.

Consider starlight first. Hydrogen, helium, and a little lithium were made in the Big Bang, but all the other chemical elements are products of nuclear reactions inside stars. In the reactions, elements that are made up of whole numbers of fused helium atoms are favoured, including oxygen, magnesium, silicon, and iron. Rocky planets form from the dispersed remnants of old stars, and the four aforementioned elements dominate the minerals inside the Earth. So even before the Kepler telescope started finding *exoplanets* (http://exoplanets.org/) (planets around other stars), physics told us that Earth-like worlds should be out there. The nature of starlight preordains a cosmos teeming with rocky planets.

What about asteroid water? All the Earth's life-giving water had to come from somewhere. Rocky planets amalgamated out of a disk of material when the Solar System formed. Computer simulations show that icy asteroids that were scattered out of a region between Mars and Jupiter were responsible for bringing most of the water to the growing Earth. Furthermore, studies of water inside meteorites support the theory.

Of course, water is only one ingredient for life as we know it, so what else was needed? Signs of extinct life in ancient terrestrial rocks provide clues. Life originated on Earth at least 3.5 to 3.8 billion years ago. Then afterwards, an alien landscape devoid of animals and large plants persisted for the next 3 billion years in part because of the lack of abundant oxygen. In fact, genetics suggest that the common ancestor of all life today was a microbe that lived in conditions of 80-100°C and negligible oxygen. Today, the study of microbes in similar environments below the Earth's surface or in warm, fractured seafloor provides hints about early life.



(https://42796r1ctbz645bo223zkcdl-wpengine.netdna-ssl.com/wp-content/uploads/2013/10/astro.jpg)Evolutionary obstacles may be the reason why it took a long time for single-celled life to evolve into animals and large plants. One tricky step was evolving the right type of cell. Of the three basic types on Earth, only eukaryote (http://www.oxforddictionaries.com/definition/english/eukaryote) cells form large multicellular organisms, unlike the microbial cells of bacteria or archaea. (http://www.oxforddictionaries.com/definition/english/archaea) A second hurdle was that the atmosphere had to become oxygen-rich to enable large organisms to exist and breathe. Astrobiologists study whether such steps were difficult or easy to provide insight into the possible prevalence of complex, Earth-like life elsewhere.

Unlike the demands of complex life, biologists have found microbes (*extremophiles* (http://www.eoearth.org/view/article/160977/)) that are adapted to environmental extremes such as temperature, acidity, pressure, and salinity. As a result, it's not unreasonable that extremophiles might live below the surface of Mars or in salty, high-pressure oceans deep inside the icy moons in the outer Solar System.

In fact, the possibility of life existing (or having existed) elsewhere in our own Solar System is far from settled. Mars gets the most press (http://www.bbc.co.uk/science/space/solarsystem/collections/life_on_mars) but many other bodies are candidates. Objects with possible subsurface seas and potential life include Ceres (the largest asteroid); Europa, Ganymede, and Callisto (moons of Jupiter); Titan, Enceladus, and Rhea (moons of Saturn); Titania and Oberon (moons of Uranus); Triton (Neptune's largest moon); and finally Pluto and similar icy dwarf planets beyond Pluto. Life may also have originated and gone extinct on ancient Venus before its surface evolved to today's hellish 460°C and an air pressure of 93 atmospheres pressure. Only future exploration can tell.

One certainty is that new discoveries of exoplanets promise a busy future for astrobiology. It's just a matter of time before we know about the atmospheres and surfaces of Earth-like exoplanets. Many peculiar worlds will also be found: dead planets with pure carbon-dioxide atmospheres, worlds covered entirely with glinting oceans, and young planets so close to their parent star that they're shedding atmospheres of steam to space. But on benign worlds, the possibility of life will be of intense interest. Welcome to astrobiology and trying to understand life here and elsewhere!

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After a doctorate at the University of Oxford, he worked as a planetary scientist at NASA's Ames Research Center near San Francisco, from 1995-2001. In 2001, he was appointed as one of the world's first astrobiology professors at the University of Washington in Seattle. From 2005-2008, Prof. Catling was European Union Marie Curie Chair in Earth System and Planetary Studies at the University of Bristol, before returning to Seattle in 2009. He has taught astrobiology courses for over a decade and has published over eighty papers and articles in areas ranging from the geology of Mars, to the biochemistry of complex life, to the co-evolution of Earth's atmosphere and biosphere.

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