**Article**

# The Search for Life in the Universe

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The recent discovery of about half a dozen planets around stars other than the Sun has triggered tremendous public interest. Attention was driven not so much by the discovery of extra-solar planets, but by the prospect of them hosting intelligent life. In any case, the media frenzy that followed was somewhat out of proportion with the events. Why? Because planets cannot be all that rare in the universe if the Sun happens to have a bunch of them. Also, the newly discovered planets are all oversized gaseous giants that resemble Jupiter, which means no convenient surface exists upon which life as we know it could live. And even if they were teeming with buoyant aliens, the odds against these life forms being intelligent may be astronomical.

Ordinarily, there is no riskier step that a scientist (or anyone) can take than to make sweeping generalizations from just one example. At the moment, life on Earth is the only known life in the universe, but there are compelling arguments to suggest we are not alone. Indeed, *most* astrophysicists accept the probability of life elsewhere. The reasoning is easy: if our solar system is not unusual, then there are so many planets in the universe that, for example, they out-number the sum of all sounds and words ever uttered by every human who has ever lived. To declare that Earth must be the only planet in the universe with life would be inexcusably bigheaded of us.

Many generations of thinkers, both religious and scientific, have been led astray by anthropocentric assumptions, while others were simply led astray by ignorance. In the absence of dogma and data, it is safer to be guided by the notion that we are not special, which is generally known as the Copernican principle, named for the Polish astronomer Nicholas Copernicus who, in the mid 1500s, put the Sun back in the middle of our solar system where it belongs. In spite of a third century B.C. account of a sun-centered universe (proposed by the Greek philosopher Aristarchus), the Earth-centered universe was by far the most popular view for most of the last 2000 years. Codified by the teachings of Aristotle and Ptolemy, and the preachings of the Roman Catholic Church, people generally accepted Earth as the center of all motion. It was self evident: the universe not only looked that way, but God surely made it so.

While there is no guarantee that the Copernican principle will guide us correctly for all scientific discoveries to come, it has revealed itself in our humble realizations that not only is Earth not in the center of the solar system, but the solar system is not in the center of the Milky Way galaxy, and that the Milky Way galaxy is not in the center of the universe. And in case you are one of those people who thinks that the edge may be a special place, then we are not at the edge of anything either.

A wise contemporary posture would be to assume that life on Earth is not immune to the Copernican principle. If so, then how can the appearance or the chemistry of life on Earth provide clues to what life might be like elsewhere in the universe?

I do not know whether biologists walk around every day awestruck by the diversity of life. I certainly do. On this single planet called Earth, there co-exist (among countless other life forms), algae, beetles, sponges, jellyfish, snakes, condors, and giant sequoias. Imagine these seven living organisms lined up next to each other in size-place. If you didn't know better, you would be hard-pressed to believe that they all came from the same universe, much less the same planet. Try describing a snake to somebody who has never seen one: "You gotta believe me. There is this animal on Earth that 1) can stalk its prey with infrared detectors, 2) swallows whole live animals up to five times bigger

**Questions**

Why is it risky to make generalizations from one example?

Why does the author believe it may be logical to assume the universe has life outside Earth?

than its head, 3) has no arms or legs or any other appendage, yet 4) can slide along level ground at a speed of two feet per second!"

Given the diversity of life on Earth, one might expect a diversity of life exhibited among Hollywood aliens. But I am consistently amazed by the film industry's lack of creativity. With a few notable exceptions such as life forms in *The Blob* (1958) and in *2001: A Space Odyssey* (1968), Hollywood aliens look remarkably humanoid. No matter how ugly (or cute) they are, nearly all of them have two eyes, a nose, a mouth, two ears, a head, a neck, shoulders, arms, hands, fingers, a torso, two legs, two feet - and they can walk. From an anatomical view, these creatures are practically indistinguishable from humans, yet they are supposed to have come from another planet. If anything is certain, it is that life elsewhere in the universe, intelligent or otherwise, will look at least as exotic as some of Earth's own life forms.

Why does the author believe the diversity of life on Earth is important to the thesis of this essay?

The chemical composition of Earth-based life is primarily derived from a select few ingredients. The elements hydrogen, oxygen, and carbon account for over 95% of the atoms in the human body and all known life. Of the three, the chemical structure of carbon allows it to bond readily and strongly with itself and with many other elements in many different ways, which is why we are considered to be carbon-based life, and which is why the study molecules that contain carbon is generally known as "organic" chemistry. Curiously, the study of life elsewhere in the universe is known as exobiology, which is one of the few disciplines that attempts to function with the complete absence of first-hand data.

Is life chemically special? The Copernican principle suggests that it probably isn't. Aliens need not look like us to resemble us in more fundamental ways. Consider that the four most common elements in the universe are hydrogen, helium, carbon, and oxygen. Helium is inert. So the three most abundant, chemically active ingredients in the cosmos are also the top three ingredients in life on Earth. For this reason, you can bet that if life is found on another planet, it will be made of a similar mix of elements. Conversely, if life on Earth were composed primarily of, for example, molybdenum, bismuth, and plutonium, then we would have excellent reason to suspect that we were something special in the universe.

How does the simplicity of the chemicals that make up life fit in with his thesis? How does this fit in with his thoughts about the diversity of life?

Appealing once again to the Copernican principle, we can assume that the size of an alien organism is not likely to be ridiculously large compared with life as we know it. There are cogent structural reasons why you would not expect to find a life the size of the Empire State Building strutting around a planet. But if we ignore these engineering limitations of biological matter we approach another, more fundamental limit. If we assume that an alien has control of its own appendages, or more generally, if we assume the organism functions coherently as a system, then its size would ultimately be constrained by its ability to send signals within itself at the speed of light--the fastest allowable speed in the universe. For an admittedly extreme example, if an organism were as big as the entire solar system (about 10 light-hours across), and if it wanted to scratch its head, then this simple act would take no less than 10 hours to accomplish. Sub-slothlike behavior such as this would be evolutionarily self-limiting because the time since the beginning of the universe may be insufficient for the creature to have evolved from smaller forms of life over many generations.

How about intelligence? When Hollywood aliens manage to visit Earth, one might expect them to be remarkably smart. But I know of some that should have been embarrassed at their stupidity. During a four-hour car trip from Boston to New York City, while I was surfing the FM dial, I came upon a radio play in progress that, as best as I could determine, was about evil aliens that were terrorizing Earthlings. Apparently, they needed hydrogen atoms to survive so they kept swooping down to Earth to suck up its oceans and extract the hydrogen from all the $H_2O$ molecules. Now those were some dumb aliens. They must not have been looking at other planets en route to Earth because Jupiter, for example, contains over 200 times the entire mass of Earth in pure hydrogen. I guess nobody ever told them that over 90 percent of all atoms in the universe are hydrogen.

And how about all those aliens that manage to traverse thousands of light years through interstellar space, yet bungle their arrival by crash-landing on Earth?

Then there were the aliens in the 1977 film *Close Encounters of the Third Kind*, who, in advance of their arrival, beamed to Earth a mysterious sequence of repeated digits that were eventually decoded to be the latitude and longitude of their upcoming landing site. But Earth longitude has a completely arbitrary starting point - the prime meridian - which passes through Greenwich, England by international agreement. And both longitude and latitude are measured in peculiar unnatural units we call degrees, 360 of which are in a circle. Armed with this much knowledge of human culture, it seems to me that the aliens could have just learned English and beamed the message, "We're going to land a little bit to the side of Devil's Tower National Monument in Wyoming. And since we're coming in a flying saucer we won't need the runway lights."

The award for dumbest creature of all time must go to the alien from the original 1983 film *Star Trek, The Motion Picture*. *V-ger*, as it called itself (pronounced vee-jer) was an ancient mechanical space probe that was on a mission to explore and discover and report back its findings. The probe was "rescued" from the depths of space by a civilization of mechanical aliens and reconfigured so that it could actually accomplish this mission for the entire universe. Eventually, the probe did acquire all knowledge and, in so doing, achieved consciousness. The Star Trek crew come upon this now-sprawling monstrous collection of cosmic information at a time when the alien was searching for its original creator and the meaning of life. The stenciled letters on the side of the original probe revealed the characters *V* and *ger*. Shortly thereafter, Captain Kirk discovers that the probe was *Voyager 6*, which had been launched by humans on Earth in the late twentieth century. Apparently, the *oya* that fits between the *V* and the *ger* had been badly tarnished and was unreadable. Okay. But I have always wondered how *V-ger* could have acquired all knowledge of the universe and achieve consciousness yet not know that its real name was *Voyager*.

And don't get me started on the recently released summer blockbuster *Independence Day*. I find nothing particularly offensive about evil aliens. There would be no science fiction film industry without them. The aliens in Independence Day were definitely evil. They looked like a genetic cross between a Portuguese Man of war jelly fish, a hammer-head shark, and a human being. While more creatively conceived than most Hollywood aliens, why are their flying saucers equipped with upholstered high-back chairs with arm rests?

I'm glad that, in the end, the humans win. We conquer the Independence Day aliens by having a Macintosh laptop computer upload a software virus to the mothership (which happens to be 1/5 the mass of the Moon), which disarms its protective force field. I don't know about you, but I have trouble just uploading files to other computers within my own department, especially when the operating systems are different. There is only one solution. The entire defense system for the alien mothership must have been powered by the same release of Apple Computer's system software (version 7.5.2) as the laptop computer that delivered the virus.

Why does the author, who is a scientist, spend so much time discussion science fiction aliens? How does that fit in with his thesis? In other words, what is the purpose of this section of the essay?

Thank you for indulging me. I had to get it all off my chest.

Let us assume, for the sake of argument, that humans are the only species in the history of life on Earth to evolve high-level intelligence. (I mean no disrespect to other big-brained mammals. While most of them cannot do astrophysics, my conclusions are not substantially altered if you wish to include them.) If life on Earth offers any measure of life elsewhere in the universe, then intelligence must be rare. By some estimates, there have been more than ten billion species in the history of life on Earth. It follows that among all extraterrestrial life forms we might expect no better than about one in ten billion to be as intelligent as we are, not to mention the odds against the intelligent life having an advanced technology *and* a desire to communicate through the vast distances of interstellar space.

On the chance that such a civilization exists, radio waves would be the communication band of choice because of their ability to traverse the galaxy unimpeded by interstellar gas and dust clouds. But humans on Earth have only understood the electromagnetic spectrum for less than a century. More depressingly put, for most of human history, had aliens tried to send radio signals to earthlings we would have been incapable of receiving them. For all we know, the aliens have already done this and unwittingly concluded that there was no intelligent life on Earth. They would now be looking elsewhere. A more humbling possibility would be if aliens had become aware of the technologically proficient species that now inhabits Earth, yet they had drawn the same conclusion.

What does the author mean by the last sentence of this paragraph?

Our life-on-Earth bias, intelligent or otherwise requires us to hold the existence of liquid water as a prerequisite to life elsewhere. A planet's orbit should not be too close to its host star, otherwise the temperature would be too high and the planet's water content would vaporize. The orbit should not be too far away either, or else the temperature would be too low and the planet's water content would freeze. In other words, conditions on the planet must allow the temperature to stay within the 180 degree (Fahrenheit) range of liquid water. As in the three-bowls-of-food scene in the fairy tale *Goldilocks and the Three Bears*, the temperature has to be just right. When I was interviewed about this subject recently on a syndicated radio talk show, the host commented, "Clearly, what you should be looking for is a planet made of porridge!"

While distance from the host planet is an important factor for the existence of life as we know it, other factors matter too, such as a planet's ability to trap stellar radiation. Venus is a textbook example of this "greenhouse" phenomenon. Visible sunlight that manages to pass through its thick atmosphere of carbon dioxide gets absorbed by Venus's surface and then re-radiated in the infrared part of the spectrum. The infrared, in turn, gets trapped by the atmosphere. The unpleasant consequence is an air temperature that hovers at about 900 degrees Fahrenheit, which is much hotter than we would expect knowing Venus's distance to the Sun. At this temperature, lead would swiftly become molten.

The discovery of simple, unintelligent life forms elsewhere in the universe (or evidence that they once existed) would be far more likely and, for me, only slightly less exciting than the discovery of intelligent life. Two excellent nearby places to look are the dried riverbeds of Mars, were there may be fossil evidence of life from when waters once flowed, and the subsurface oceans that are theorized to exist under the frozen ice layers of Jupiter's moon Europa. Once again, the promise of liquid water defines our targets of search.

Other commonly invoked prerequisites for the evolution of life in the universe involve a planet in a stable, nearly circular orbit around a single star. With binary and multiple star systems, which comprise about half of all "stars" in the galaxy, planet orbits tend to be strongly elongated and chaotic, which induces extreme temperature swings that would undermine the evolution of stable life forms. We also require that there be sufficient time for evolution to run its course. High-mass stars are so short-lived (a few million years) that life on an Earth-like planet in orbit around them would never have a chance to evolve.

Describe the many characteristics necessary for a planet to support life.

The set of conditions to support life as we know it are loosely quantified though what is known as the Drake equation, named for the American astronomer Frank Drake (now at the University of California at Santa Cruz). The Drake equation is more accurately viewed as a fertile idea rather than as a rigorous statement of how the physical universe works. It separates the overall probability of finding life in the galaxy into a set of simpler probabilities that correspond to our preconceived notions of the cosmic conditions that are suitable for life. In the end, after you argue with your colleagues about the value of each probability term in the equation, you are left with an estimate for the total number of intelligent, technologically proficient civilizations in the galaxy. Depending on your bias-level, and your knowledge of biology, chemistry, celestial mechanics, and astrophysics, you may use it to estimate from at least one (we humans) up to millions of civilizations in the Milky Way.

If we consider the possibility that we may rank as primitive among the universe's technologically competent life forms--however rare they may be--then the best we can do is keep alert for signals sent by others because it is far more expensive to send rather than receive them. Presumably, an advanced civilization would have easy-access to an abundant source of energy such as its host star. These are the civilizations that would be more likely to send rather than receive. The search for extraterrestrial intelligence (affectionately known by its acronym "SETI") has taken many forms. The most advanced efforts today uses a cleverly designed electronic detector that monitors, in its latest version, billions of radio channels in search of a signal that might rise above the cosmic noise.

The discovery of extraterrestrial intelligence, if and when it happens, will impart a change in human self-perception that may be impossible to anticipate. My only hope is that every other civilization isn't doing exactly what we are doing because then everybody would be listening, nobody would be receiving, and we would collectively conclude that there is no other intelligent life in the universe.

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Describe the concept of the Drake equation. Why is it described as "a fertile idea rather than a rigorous statement"?

Describe the author's purpose in writing this essay.

Did the author succeed in that purpose? Explain.

Develop three questions you would like to ask the author.