A Brief History of Astrobiology

By David H. Caldwell

Intro

The question of life existing outside Earth is almost as old as human civilization as we know it. The new science of astrobiology searches for signs of life on alien planets, as well as for the origin of life on our own planet. In its short history, astrobiology has greatly enhanced our knowledge in both these areas, yet this is hardly the first time these questions have been addressed.

I. The pre-NASA quest

Ancient philosophers theorized the existence of an infinite cosmos with an infinite number of worlds in it, followed by medieval intellectuals who debated the “plurality of worlds” theory. During the Renaissance Copernicus, Galileo and Kepler, as well as less-famous names such as Giordano Bruno, went against popular teachings by suggesting the existence of planets beside Earth. As astronomical technology advanced, so did the theories; from “infinite earths” came “infinite solar systems” and finally the “infinite universe” theory presented by Edwin Hubble. Astronomer Percival Lowell described Martian “channels” in the early twentieth century and theorized an advanced civilization living on the red planet. As technology advanced, so did the interest and the popular hype stemming from it in the form of science fiction; at the time of NASA’s formation the country was still in the grips of the UFO phenomenon, while movies like *Earth Vs. The Flying Saucers*, *Invasion of the Body Snatchers* and especially the remake of H.G. Wells’ *War of the Worlds* captivated and terrified audiences.

When the Soviet Union shocked the Western world with the successful launch of *Sputnik* in 1957, the United States embarked on a hastily organized scientific boom to catch up with the Soviets. Several programs dealing with origins of life on Earth as well as life outside Earth were already in progress at the time, spurred by Watson and Crick’s discovery of DNA in 1953. This breakthrough, combined with the growing theory of cosmic evolution—that the entire universe has been evolving, from the Big Bang to the present—led to the conclusion that life could easily exist on other planets, governed by the Darwinian laws of natural selection and fabricated from the same basic elements found on our planet. This would change over time as science advanced further, but it is important to note that science’s thirst for extraterrestrial knowledge dates even before the Space Age began.

II. A shaky entrance

Almost immediately after President Dwight D. Eisenhower signed the National Aeronautics and Space Act creating NASA in July 1958, the Agency’s first Deputy Administrator, Hugh Dryden, approached the National Academy of Sciences to set up a Space Sciences Board (SSB) to advise NASA. With Nobel Prize-winning microbiologist Joshua Lederberg leading the subpanel on extraterrestrial life, the new science of exobiology began to investigate the origins of life on Earth as well as life outside Earth. Experiments recreating Earth’s early atmosphere and the first gas chronometers—instruments that analyze and determine the chemical makeup of a compound—were some of the earliest intended projects. Less than six months later the exobiology program received its first formal grant, for a life-detecting experiment called the Wolf Trap (named for its creator, Dr. Wolf V. Vishniac), and by 1960 a formal exobiology program was established at NASA's Ames Research Center in California. While NASA took its first steps into space with the Vanguard and Mercury programs, the exobiologists worked to develop life-detecting instruments as well as surveying instruments to be carried on future NASA spacecraft.

This was not without opposition, however. Some scientists, particularly physical scientists, regarded exobiology as a "science in search of a subject," arguing that exobiology's value had yet to be proven and its funding should go to more practical NASA applications. Yet exobiology-related research on NASA probes helped it advance its science of understanding the universe from the very beginning; Explorer 1, NASA's first successful space probe launched in January 1959, discovered the Van Allen radiation belts surrounding the Earth. Modified versions of exobiology-developed soil analysis instruments were carried on the Surveyor probes which landed on the Moon in the mid-1960s, analyzing its makeup and, to a limited degree, the Moon's geological history. As NASA worked to meet President Kennedy's task of landing astronauts on the Moon by the end of the decade, the Agency was also continually planning ahead: designing and testing space probes to nearby planets, while the exobiology program worked tirelessly on instruments capable of analyzing soil samples millions of miles from Earth. These probes would later be revisited in later years when their missions received additional financial support—at this time the Apollo program enjoyed the Lion's share of NASA funding—and would become NASA's most successful robotic missions.

III. Viking to Mars

However exobiology's most ambitious missions have gone to humanity's closest yet most mysterious neighbor: Mars. The Red Planet has long occupied a special place in humanity's alien belief, since American astronomer Percival Lowell observed "channels" on the Martian surface in the early 20th century and surmised they were the work of an advanced Martian civilization. Mars appealed to exobiologists as the most Earth-like planet, and they theorized that studying Mars could reveal much about Earth's early history. The theory that life on Earth began as single-celled bacteria was very new at the time, and exobiologists believed that finding primitive life on Mars would vindicate this theory.

Sending space probes to Mars and the Martian surface had been discussed from NASA's start, but only by the mid-1960s did NASA have the technology to be able to launch and control space probes that far from Earth. From 1964 to 1971 four separate space probes made flybys of the planet coming within fourteen miles of it; their surface photography, however, disproving any notions of a Martian civilization. (Astronomer Carl Sagan retorted that from fourteen miles up, Earth showed no signs of life either.) A more advanced mission capable of landing on the surface came next. 1960's Project Voyager –not to be confused with the unmanned Voyager probes from the late 1970s—planned an orbiting probe capable of releasing a capsule down onto the Martian surface by the end of the decade. This first interplanetary landing project is now known by its later name: Project Viking.

The Viking program proposed to transport two spacecraft to Mars, where each would send a lander to the Martian surface. While the orbiters took surface images the landers would relay their findings from the surface to the orbiter, which would in turn relay them back to Earth. In addition to surveying instruments and cameras, the probes would also carry three sophisticated biological experiments to test Martian soil for evidence of life. These experiments alone cost $100 million, raising Viking's price tag to $1 billion ($3.74 billion if attempted today). It was an unprecedented mission, and remains among the most expensive NASA missions to date. Arriving at Mars in the summer of 1976, the two Viking landers analyzed Martian soil samples as well as surveying Mars' atmosphere, surface geology and weather. Hopes were high in the exobiological community that Viking would find proof of extraterrestrial life, an incredible accomplishment for its own sake, and thereby a glimpse of how life might have begun on Earth.

IV. Changing perspectives

Yet despite high hopes from NASA and the exobiologists, the Viking landers failed to find conclusive evidence of life on Mars. The scientific community's hope for finding Martian microbes had been dashed but exobiology and knowledge of Mars greatly increased. Although Mars is not believed to possess life at the present time, the planet's geology strongly suggests the presence or at least the possibility of life in the past. In fact, controversy over the Viking results has continued to this day, as some voices claim the instruments were faulty and experiments designed to detect organic materials in Martian soil failed to find any, yet the presence of channels and giant canyons such as the Valles Marineris are indisputable proof that water once existed on Mars. The idea of water on Mars has continued to drive exploration of the Red Planet.

Despite Viking's failure to confirm evidence of life on Mars, the remainder of the 1970s brought with it new gains in other fields. In 1979 humans first visited deep-sea hydrothermal vents and instead of finding them devoid of life discovered an entire new ecosystem of species, proving that life can exist in surroundings previously thought uninhabitable. In addition, the rich chemicals exuded by the vents created a sea perhaps not unlike the Earth's early oceans nearly 4 billion years ago, providing new scientific research opportunities. 1979 also brought the publication of the Gaia hypothesis, now a mainstay of ecological theory. The hypothesis theorizes that all surface geography of the Earth—the atmosphere, oceans and the Lithosphere (or the outermost layer of the Earth's crust) are interrelated, and only the sum of those parts working in symbiosis allowed life to exist on Earth. The theory's original proponent, Dr. James Lovelock, insisted that such an intricate balance was necessary for the presence of life on Earth, and thirty years later the hypothesis is widely accepted among scientists. The hypothesis led to a heightened search for "Earth-like" planets with environmental characteristics similar to our own.

Alternatively a "carbon chauvinism" theory also emerged, arguing against limiting possible alien life to carbon-based life on Earth-like planets. Cellular biologist Lynn Margulis breathed new life into the proposed endosymbiosis theory in 1981. This theory, first proposed by Russian botanist Konstantin Mereschkowski in 1905, argues that the cellular organelles known as mitochondria evolved as autonomous eukaryotic cells and were incorporated into more developed cells. Two Pioneer and two Voyager space probes became the first man-made objects to the outer planets in the 1960s and 70s, and in addition to their instruments carried plaques that theoretical alien species might recover in the future. These advances and missions proved that despite Viking's failure to find definitive proof of Martian life, exobiology was far from lost.

V. SETI

In the wake of sweeping budget cuts on NASA future programs, a new strategy was needed. While development on what would become the Space Shuttle continued, NASA looked to the stars. It was at this point that arguably the most famous aspect of exobiology entered the public view. SETI, or the Search for Extraterrestrial Intelligence, intended to use radio telescopes to search for signs of extraterrestrial civilizations. The exact date SETI began is difficult to pinpoint; talk on the subject dates back to 1959, though a reasonable starting date would be the unveiling of the famous Drake Equation in November 1960. This equation, postulated by radio astronomer and SETI pioneer Dr. Frank Drake, effectively estimated the number of extraterrestrial civilizations in our galaxy based on the number of stars. The number of theoretical civilizations even then (when not as many stars were believed to exist in our galaxy as today) was so large that the astronomers at SETI were confident contact would be made within a generation. Today, if the Drake Equation is applied to the current knowledge of our galaxy, the estimated number of Earth-like planets is approximately 10 billion. With this new set of beliefs, SETI expanded from one radio telescope in West Virginia to arrays across the country, the largest at Ohio State University—colloquially known as "Big Ear".

NASA's involvement in SETI dates to 1971, when the agency funded a SETI study which proposed a 1,500-dish array known as Project Cyclops. The array was never built, due to the $10 billion price tag, but the study influenced much of SETI's more recent work. Over the next two decades, NASA was present in some of SETI's most famous moments, such as the Arecibo message in 1974, which sent a greeting from Earth to a galaxy 25,000 light years away, as well as the reception of the "Wow! signal," (an unusually strong and sophisticated signal, believed by some to have extraterrestrial origins) in 1977. NASA also helped SETI develop more sophisticated astronomical technology, such as a 1981 portable spectrum analyzer nicknamed "Suitcase SETI" capable of observing 131,000 frequencies. However SETI's most ambitious project would prove to end NASA's connection with the astronomical group. In 1979 NASA proposed an official project (its first full-fledged project with SETI) known as the Microwave Observing Program (MOP), intended to be a long-term observation of the sky, on 15 million channels. Due to extensive planning, the program could not begin until the early 1990s, and within a short time it became increasingly difficult to sustain for budgetary reasons. The program's monetary problems caught the attention of Congress and thus the public, and in 1993 Congress cut the NASA funding to SETI once and for all. SETI continued on private funding and is still active today; SETI is now collaborating with UC Berkley to create a massive new telescope in southern California.

VI. Metamorphosis

By the early 1990s, however, exobiology's future was jeopardized by funding restrictions. NASA's Ames Research Center in California had long been home of a large portion of NASA's Earth Science and Space Science research, yet in 1995 NASA was again facing unprecedented budget cuts which intended to drop programs dealing with planetary and life science. Ames in particular possessed impressive programs in life, Earth and space science, all of which threatened to be closed down with these budget cuts. To prevent this, NASA pragmatically decided to combine and restructure these programs into one fluid discipline. This discipline, NASA proposed, would address the "Origin and Distribution of Life in the Universe," through both NASA research centers like Ames as well as universities across the country. In addition to searching for estraterrestrial life under exobiology, "astrobiology" would also investigate the early history of life on our own planet as well as the early history of the universe. The issues astrobiology proposed to address were already being addressed by NASA, but astrobiology proposed to go beyond what one discipline could do through knowledge-sharing and pooling resources. The word "astrobiology" was first used in official NASA lingo on May 30, 1995, and by February 1996 it was included for the first time on an official document—NASA's Strategic Plan for that year.

The program hit the ground running in 1998 with the Astrobiology Roadmap, the first of three documents to bear that name, in which a dedicated team outlined astrobiology's three main goals and the disciplines' underlying principles. In short, the roadmap not only expressed what astrobiology was about, it showed were it was going—hence the name. From the first edition to its most recent iteration in 2008, the roadmap expanded as astrobiology's knowledge of the universe expanded. In addition to laying out the program's goals and principles, the roadmap could now back up astrobiology's arguments with real data from missions. The fledgling science was on its way.

VII. Astrobiology and the Mars Rock

Reorganizing exobiology into astrobiology came not too soon, as it would turn out. Barely six months after its founding came the event that would vindicate astrobiology and spawn new projects. On the 6th of August, 1996, an article in *Science* magazine revealed that a Martian meteorite discovered in Antarctica fourteen years earlier might contain evidence of extraterrestrial bacteria. It was not the first time a meteorite from Mars had exotic contents; by April 2004 thirty Martian meteorites were known to contain traces of Martian gases millions of years old. However through the utilization of powerful electron microscopes, scientists had discovered what appeared to be fossilized extraterrestrial life. Once again, NASA and extraterrestrial life were in the public spotlight. Public interest, fueled again by popular culture with summer blockbusters like *Independence Day*, was so high that even President Bill Clinton addressed the nation on the subject. While the scientific community struggled to come up with a definitive analysis of the meteorite, the public held its breath.

However, the scientific community could not agree that the contents of the meteorite were Martian bacteria—indeed, if it was even life at all. Once again, NASA's hopes for finding life on Mars (even extinct life) were put on hold, though, like Viking, debate and analysis of the results continue to this day. However, the intensive scientific investigation of the meteorite and especially the passionate debate reiterated the need for an interdisciplinary science, as the meteorite's geology, chemistry and biology were all necessary components in determining exactly what the meteorite contained. Without the reorganization of all those fields under the banner of astrobiology, an in-depth investigation of the meteorite would have taken far longer and might not have happened at all. Two years later the NASA Astrobiology Institute (NAI) was christened as a headquarters for NASA's astrobiology studies, centered at Ames and operating in cooperation with other NASA research centers and universities across the country. The NAI would incorporate existing exobiology programs with planetary and life science programs at NASA Research Centers such as Langley Research Center in Virginia and Goddard Space Center in Maryland.

VIII. The Twenty-First Century

In the present decade, astrobiology has continued coming into its own. The Mars Global Surveyor discovered "gully washers" leading into the Valles Marinaris canyon in 2000. Not only did this discovery further advance the theory for water on Mars, but geologists determined that the formations themselves are only a few million years old—very new, in geological terms, meaning water existed on Mars not billions of years ago (as previously thought) but much more recently. The rovers Spirit and Opportunity landed in 2004 and are going strong five years later, lasting longer than any foreseen expectations. The Mars Odyssey probe continued its scientific investigation and in 2007 discovered what might be Martian caves, the only natural structures on the planet capable of protecting primitive lifeforms against meteorites and cosmic rays. In March 2008, a team at NASA's Jet Propulsion Laboratory made the first-ever discovery of organic compounds on a planet outside our solar system; using the Hubble Space Telescope, methane and water were discovered on an exoplanet closely orbiting a Jupiter-sized star roughly sixty-three light-years from Earth. The presence of methane and water on such a hot planet further argues that life is not limited to Earth-like planets.

At the time of this writing, The Spitzer Space Telescope is observing distant solar systems and the W.M. Keck Observatory in Hawaii is investigating solar system formation as well as creation of the universe itself, while the Kepler Mission is surveying the Milky Way to search for Earth-like planets. The *Dawn* mission is en route to the asteroid Vesta and dwarf planet Ceres, two of the largest and oldest protoplanets in our solar system. *Dawn* will help NASA and astrobiologists learn more about the formation and early history of our solar system. The *Mars Odyssey*, Mars Global Surveor and the two rovers *Spirit* and *Opportunity* are all on or orbiting Mars, enhancing our knowledge of the planet long after their respective missions were due to end. Most recently, in January 2009 science's image of Mars as a dead planet was shaken when a NASA team led by Dr. Michael Mumma discovered substantial plumes of methane. As methane evaporates quickly in Mars' thin atmosphere, the presence of large quantities of the gas is evidence of either intense geological activity or Martian microbial life. Plumes of methane have been documented as far back as 2003, but this is the first time a steady stream of the gas has been discovered on Mars. Whatever its origin, the methane changes our perspective on Mars considerably.

Astrobiology's role in NASA can be seen clearly through these missions, and there's a lot more on the way. The Mars Science Laboratory Rover (MSL) or "Curiosity" is scheduled to launch in 2011 and usher in a new era in NASA's exploration of the Red Planet. The largest and most complex rover built to date, MSL will further advance what Viking began in 1976, analyzing soil samples across the planet—not just in one place, like Viking—and gaining a much broader survey of Mars' geological makeup. MSL's unprecedented mission will usher in a new age in interplanetary exploration and hopefully inspire new missions to Mars as the 21st century continues. Over the next decade, Mars will continue to serve as astrobiology's next goal, with proposed missions to return samples, drill deep into Mars' crust to deploy instruments and even deploy what is known at this point as the Astrobiology Field Laboratory, a mission intended specifically to follow MSL in analyzing Mars' potential for supporting life.

IX. The Future

Planned NASA projects relating to Astrobiology include the much-discussed Terrestrial Planet Finder (referred to as the "Holy Grail" by some astrobiologists), a large space telescope designed to examine previously discovered "exoplanets" or Earth-like planets in distant solar systems. Since the first planet was discovered orbiting a Sun-like star in 1995, the number of exoplanets in our galaxy is rising steadily and is presently above three hundred. The Terrestrial Planet Finder has been in development since 1992 and will not investigate elemental traces but entire planets, hoping to find extraterrestrial life or even civilizations. The TPF represents the ultimate astrobiological project, and when it is finally completed the TPF will be able to observe a range of nearly 500 nearby stars in our "solar neighborhood."

Within our own solar system, astrobiology's main prize remains Mars, but another likely candidate for extraterrestrial life is Jupiter's moon Europa. Surface imaging by both Pioneers, both Voyagers and the Galileo probe has revealed that the moon is covered with thick water ice, under which likely lies a vast ocean of liquid water. Firmly established as a necessary spawning ground for life, the presence of water on Europa greatly increases its chances of supporting extraterrestrial life. Additionally Saturn's moons Titan and Enceladus are also candidates for life within our solar system, Titan due to its atmosphere and Enceladus due to its tectonic activity and geological makeup.

In such a massive field, however, NASA is hardly the sole player. Cooperation is the key to success in Astrobiology, not merely between disciplines and organizations but between countries. To that end NASA and the European Space Agency have cooperated and are still cooperating on a variety of astrobiology-related missions, such as the Hubble Space Telescope and the Kepler Mission. Future joint missions are currently being debated, such as the James Webb Space Telescope and a mission to Europa currently scheduled sometime in the next decade. Astrobiology is a multi-disciplinary field attempting to answer some of the oldest and toughest questions in science, and NASA can't do it alone. The agency hopes to remain at the forefront of astrobiology, but as the subject is so vast cooperation is necessary for progress.

NASA's interest in life on other worlds, as well as further understanding life on our own, extends as far back as the Agency itself. The development of the exobiology program and its subsequent metamorphosis into astrobiology has integrated NASA's resources into an unprecedented scientific juggernaut. Missions through astrobiology have provided the scientific community with information never thought possible years ago, and the program has planned well into the twenty-first century. We can't wait to see what's next.