How ‘alien genetics’ would change our understanding of life, biology and evolution

What would be the most profound scientific discovery ever? I suppose that different people might propose different answers to that question. Much of the public, as well as many people in the media, would probably focus on important practical applications of science, such as a “cure for cancer.”

For me, however, the answer would be the discovery of life on another planet. I grew up during the 1960s—during NASA’s Apollo missions, the original *Star Trek*, and *2001: A Space Odyssey*. My mind has always been fascinated by outer space and the possibility of space aliens. I believe that the discovery of life on another world—even microbial life—would be profound, because it would represent a totally new dimension of scientific exploration and a fundamental shift in our understanding of the universe.

The first evidence of biological processes beyond our home planet would raise the question: How similar or different would that alien, extraterrestrial biology be compared with Earth-bound, terrestrial biology?

All living things on Earth—from a bacterium to a tree to a human being—are based on the nucleic acids DNA and RNA. That is how life evolved on Earth. But did life evolve the same way on other worlds?

If we ever find life on another world—such as Mars, Europa (a moon of Jupiter), Enceladus or Titan (moons of Saturn), Triton (a moon of Neptune), or a planet circling another star—scientists will want to determine if it too is based on DNA/RNA. If not, what kind of alien system of genetic coding does it have? Moreover, if we come across extraterrestrial life, will we even recognize it as life if it does not have the same nucleic acids and metabolism with which we are familiar?

The answers to these questions will reveal a treasure trove of insights into the origin and evolution of life, the nature of biology, and the characteristics of the cosmos.

cosmos Image not found or type unknown

Research into possible alien genetics

While we await our “first contact” with alien life, scientists are conducting a variety of studies investigating possible scenarios for alien genetics and extraterrestrial biology.

These laboratory studies do not receive as much media attention as the endless stream of alleged UFO sightings, but they provide us with greater insight into possible space aliens. This research is revealing information about potential systems of genetics that would differ from the genetics of Earth organisms, and this information, in turn, is leading to the development of new technologies to detect and examine extraterrestrial organisms (with biochemical tests carried out by the instruments on robotic spacecraft).

Some of the most exciting research into the possible alternative genetics of extraterrestrial life is being conducted by the Foundation for Applied Molecular Evolution (FfAME), based in Alachua, Florida. In NASA-funded research reported in February 2019, a team led by biochemist and FfAME Distinguished

Fellow Steven Benner created a kind of synthetic DNA with an altered nucleotide makeup. The synthetic DNA consisted of four new nucleotide bases in addition to the normal four (adenine, cytosine, guanine, thymine), for a total of eight types of nucleotides.

The researchers' synthetic nucleic acid, nicknamed "hachimoji DNA" (Japanese for "eight letters"), was capable of storing and transmitting genetic information, replicating, and evolving through Darwinian processes. Benner said that the research "expands our understanding of the types of molecules that might store information in extraterrestrial life on alien worlds."

In an email exchange with me in August 2019, Benner provided the following additional details and insights about his research:

Q: What does your research suggest about the possibility of finding life on other planets or moons (in this solar system or elsewhere)?

A: We started our research on alternative genetic systems specifically to explore the range of possible chemical structures that might support Darwinism in general, genetics specifically. This [information] would help us search for life in the cosmos, especially life that does not share common ancestry with life on Earth. Absent this work, we would be just looking for DNA, RNA, nothing else. With this work, we know a bit more about how we should make our search less "Earth-centric." So [our research] increases greatly the possibility of finding life elsewhere. However, it does not say anything terribly strong about whether or not there is life elsewhere to detect in the first place.

Q: Do you think it is more likely that extraterrestrial life is based on DNA (similar to Earth DNA) or on some other, different type of information-coding molecule?

A: This question revolves around the degree of difference. We do not expect life elsewhere to have DNA with exactly the same chemical structure as the DNA that you and I have. Indeed, even on Earth, a few scattered organisms have evolved slightly different building blocks for their genetic systems. [Differences and similarities are] simply a matter of degree. Thus, thymine is similar to uracil [an RNA nucleotide], if you think that a methyl (CH_3) group is "similar" to hydrogen (H). What you think is similar in terms of molecular structure tells us more about you and your training than about the molecules.

Q: Are there any particular planets or moons where you think life might be most likely?

A: We spent many years researching alternative liquids were life, and genetics in particular, might exist. That research has reinforced the view that water or another high-temperature liquid [a substance that is liquid at high temperatures, such as on Earth] is the only place to find Darwinism. Low-temperature solvents [substances that are liquid at low temperatures, such as on some of the outer planets' moons], like methane on Titan or liquid nitrogen on Triton, do not have the solubilizing power adequate to support even the basics of metabolism or genetics. Therefore, we are looking at the subsurface on Enceladus and

Europa [which might have subsurface oceans of liquid water heated by tidal pull from their parent planets], and also on Mars, [as] the most likely places to find alien biology. [We are interested in these worlds] partly because [life] is most likely to exist there, but also because the missions that would be sent to find it are the most manageable.

Q: Would you expect non-DNA life (including microbes) to look and act different from Earth-type life, or would it still be recognizable to us as life?

A: Life universally will follow the same rules of chemistry, and, therefore, there will be many similarities. In water, for example, [with] around neutral pH, all of life will use the reactivity of the carbonyl (C=O) group to support metabolism, which will heavily involve [chemical] species that carry a molecular charge. All [life] will use hydrophobic molecules to form [cellular] compartments. However, the molecules will be different in their details. Indeed, here on Earth, the hydrophobic molecules that are used to form compartments are different from kingdom to kingdom [Archaebacteria, Eubacteria, Protista, Fungi, Plantae, Animalia].

human hybrid

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Other research

In July 2019, chemists Vladimir Kubyshkin and Nediljko Budisa, both of the Technical University of Berlin and University of Manitoba, published their ideas about alternative genetic codes that would produce different kinds of amino acids (“non-canonical amino acids”) than are produced by the natural nucleotide codons on Earth.

Whereas most amino acids that are encoded by natural DNA nucleotides are derivatives of alanine, noted the researchers, this “alanine world” is not necessarily the only kind of world possible. They described the evolutionary steps that led to the “alanine world” on Earth, suggesting that evolution might have taken

different paths under different circumstances—such as the development of a “proline world.” They proposed that biochemically engineered alterations in a synthetic genetic code would enable the “complete redesign or even *de-novo* creation of living organisms based on entirely different chemical make-up, with [a] completely new set of solutions for both near and distant future biotechnologies.”

Although the main interest of these researchers was on biotechnology applications, their ideas also suggest that a greater diversity of life may be possible on other planets than the life produced by genetic processes on Earth.

Still other research involves altering the sugar-phosphate “backbone” of nucleic acids to create replicable molecules that are fundamentally different from DNA, but still capable of DNA-like information coding and transmission. Such synthetic “xeno-nucleic acids” (XNAs) could theoretically be used to create new life forms, because the XNA could store genetic information and transmit the information across generations.

Synthetic biologist Philipp Holliger of the Medical Research Council (MRC) Laboratory of Molecular Biology in the United Kingdom has worked extensively with XNAs. Since the early 2010s, his group has described the creation of several kinds of XNAs that have different sugar molecules or different molecules substituting for sugars, compared with natural DNA. These XNAs can store and transmit genetic information like DNA, and they can code for the production of functional enzymes. Moreover, the XNA enzymes are more chemically robust and stable than natural DNA-made enzymes.

This research suggests that biological evolutionary processes could have happened naturally on other planets without the need for either DNA or RNA. Alternative types of nucleic acids increase the potential for life to exist elsewhere beyond the confines of our own planet. However, Holliger and his colleagues have emphasized the potential medical applications of their research over any astrobiological implications.

Media and public perspectives on science

Outside of potential practical applications, is research into extraterrestrial genetics a worthwhile scientific pursuit, or is it pointless speculation?

As I suggested in my first paragraph, many people do not look beyond the practical applications of science. When scientific research is reported, the first thoughts of many people, including journalists, tend to be along the lines of, “What does this mean for me?” or “What good will this do for society?” That is partly because many scientists themselves discuss their research in those terms, as that may be the legitimate motivation behind their research.

Nevertheless, I would like to remind readers that science does not have to always produce immediate practical applications or benefits. Science for the pure sake of discovery is perhaps the most fundamentally human pursuit. Human beings following their curiosity to probe great unknown mysteries—such as the possibility of life on other planets—is a major hallmark of our species. I wish that the mass media would put more effort into occasionally presenting this perspective on science to the public.

Media reports on the possibility of extraterrestrial life tend to focus on dubious claims of UFOs. The public is unlikely to receive any enlightenment from such reports. It would be much more illuminating for people to know that the current genetics research of FfAME and other teams of scientists is expanding the chances that “we are not alone” in the universe.

A.J. Smuskiewicz is a freelance writer and editor specializing in science, medicine, world events, and cultural issues. He can be found on his website