

Searching For Aliens

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Chris McKay, a planetary scientist with the NASA Ames Research Center, is involved in nearly every investigation of interest to astrobiologists. He is working on the return to the moon with both the Lunar Precursor and Robotic Program and the Constellation Project.

As a co-investigator on the Phoenix Lander and the Mars Science Laboratory, he's deeply involved in future Mars exploration. He has long been a vocal advocate for the human exploration of Mars, and for creating a global biosphere on the Red Planet, restoring Mars to the more habitable conditions it likely had 3.5 billion years ago.

He also researches the possibilities for life on Jupiter's moon Europa and the organic chemistry of Saturn's moon Titan. Finally, to better understand the limits for life in the solar system, he often explores the coldest and driest places on the Earth.

But finding out how life on Earth adapts to extreme environments is still a far cry from imagining the weird kinds of life that could exist in much stranger environments, such as Europa, with its liquid water ocean overlain by an irradiated ice shell, or Titan, which has a thick smoggy atmosphere and methane rain pattering down on its frozen surface.

In this interview with Astrobiology Magazine editor Leslie Mullen, McKay talks about the potential for other kinds of life in the universe, and how we could begin to search for those aliens.

Astrobiology Magazine (AM): You've said that, in our investigations of

the solar system, you hope we find a completely alien life form. Could you explain what you mean by that?

Chris McKay (CM): I think one of the key goals for astrobiology should be the search for life on other planets, and in particular the search for a second genesis. And by that, I mean life that represents an independent origin from life on Earth. All life on Earth is related; all can be mapped onto a single web of life.

If there is a form of life that started separately, it might have some important differences from Earth life. It might still be DNA-based, but with a different genome than life on Earth. Or it might not be DNA-based at all.

Think of Earth life as a book written in English. There's an alphabet, there's words, and there's a language structure. A book in Spanish has the same alphabet, but it's clear that it's a different language -- there are different words with different constructions. A book in Hebrew, meanwhile, has a different alphabet. A book in Chinese doesn't even have an alphabet.

It has a completely different logic, using symbols to represent ideas or words directly. All four of those books -- English, Spanish, Hebrew and Chinese -- could be about the same topic, and therefore contain the same information. So at an ecological level they would all be the same, but they have fundamentally different ways of representing that information.

In our biology, the alphabet is A, T, C, and G -- the letters in the genetic code. The words are the codons that code for that. It could be that alien life will have the same alphabet but different words, the way Spanish is different from English. But it could be something completely different that doesn't use DNA, like the Chinese book.

AM: So if we did find a completely different basis for life, what would we learn from the comparison studies? For instance, could it help us develop a standard definition for life?

CM: It certainly will contribute to understanding life in a more general sense. But it may not contribute to a definition. In the end, we may have a complete understanding of life and still no definition. There are some things that are like that -- for example, fire.

We have a complete understanding of fire, and yet it's very hard to define it in such a way that distinguishes between a hot charcoal and a raging flame and something like the sun. Fire is a process, so it has different aspects.

Carol Cleland and Chris Chyba have said that defining life is like trying to define water before the development of modern chemistry. Once we know what it is -- H_2O -- we'll have a definition for it. But there are a lot of things that we understand and can duplicate and simulate, but we still don't have a definition for.

That's a limitation of what a definition is -- it tries to categorize things in a simple way. Some things, like a molecule of water, are ultimately simple. But a process like fire is not a simple thing, and it resists being categorized in a simple way.

Life may be that way. Even after we've discovered many examples of it, even after we can reproduce it in the lab and can tie it to fundamental physical and chemical principles, we may not have a simple definition.

AM: If there is alien life out there, how could we hope to detect it with current exploration methods?

CM: We know how to detect Earth-based life, but to detect alien life we

need a more general test. We could use a property of life that I call the LEGO Principle. Life is made up of certain blocks that are used over and over again. Life is not just a random collection of molecules.

For example, life on Earth is made up of 20 L-amino acids which form the proteins, the five nucleotide bases which form RNA and DNA, some D-sugars which form the polysaccharides, and some lipids which form the lipid membranes and fatty molecules. So that kit of molecules -- the LEGO kit of Earth -- is used to build biomass.

Life has to pick a set of molecules that it likes to use. A random distribution of organic molecules is going to have a smooth distribution, statistically-speaking. For instance, for the amino acids found in meteorites, there are no systematic differences in the concentrations of L versus D. Certainly in a Miller-Urey experiment, L- and D-amino acids are produced equally.

But for organic molecules associated with life on Earth, the distribution is not smooth.

Life uses molecules it likes in very high concentrations, and it doesn't use the molecules it doesn't like. So you're much more likely to find the L-amino acids on Earth than their D counterparts. You're much less likely to find amino acids that aren't in that set of 20 that life uses.

I think that test can be generalized if we find organic material on Mars or on Jupiter's moon Europa. We can analyze the distribution of organic molecules, and if they represent a very unusual distribution, with concentrations of certain molecules, that would be an indication of biological origin. If the molecules are different than the molecules of Earth life, then that would be an indication of an alternative biological system.

AM: Since all the planets in the solar system formed from the same basic materials, do you think life elsewhere could have the same preferences and biases as life on Earth?

CM: Certainly the places we're looking for life -- Mars and Europa -- are going to have carbon-based, water-based life, for the reasons you just said. That's what those planets are made out of; that's what is in those environments. But whether they're going to be exactly the same as Earth life at the next level of complexity is, I think, debatable. By the next level of complexity, I mean how those carbon atoms arrange to form the basic building blocks.

Some people have argued that there is only one way to do it -- that the fitness landscape of life has a single peak, and no matter where you start, life is going to climb that peak to the summit. And life anywhere is going to end up using the same molecules because they're the best, most efficient molecules. There's one best biochemistry, and we're it.

That assumes the fitness landscape is just a single peak, like Mount Fuji. But maybe the landscape is a mountain range with a bunch of peaks, and the range is not continuous. If you start in one place, there are only certain fitness peaks that you could reach, and if you start somewhere else, there's no way to get over to those peaks because there's a zone in-between that's not a viable biological system.

We don't know what the fitness landscape for life looks like. All we know is that there's one peak at least that we're sitting on, but we don't see the topography of the whole system. I would argue that organic chemistry is sufficiently complicated and diverse to have more than one single, global maximum.

AM: Do you think it might be related to a planet's environment? That there might be a peak for Earth, a peak for Mars, a peak for Europa?

That chemical systems will develop and adapt in an optimum way to their particular environment?

CM: It could be, but I would guess not. I think that as long as the environment is defined by liquid water, the differences will be just chance. The molecules that life happened to put together are what evolutionists call "frozen accidents."

Life uses L-amino acids, but why not D-amino acids? We don't think there's any selective pressure of L versus D. It's a trivial difference. Perhaps life just had to choose one or the other.

It's like driving, where everybody has to drive on one side of the road. It really doesn't matter if everybody drives on the left, like England, or on the right, like most of the rest of the world. The fact that England drives on the left and others drive on the right is just a frozen accident. It would be very hard to change now, but there's no fundamental physical reason why they drive on the left and we drive on the right. It's a historical artifact.

My guess is that a lot of biochemistry is just a historical artifact. Where you start off in this biochemical landscape determines where you end up, and you end up at the optimum near you.

Whereas if you start off, for some reason, someplace differently, you might end up in a completely different optimum, with a completely different set of molecules -- all operating in water because that's the medium that all these environments that we're looking at have in common. Because they have water in common, the range of possible environmental influences, I think, is small.

AM: But if that were true, then why aren't there multiple unrelated forms of life on Earth?

CM: I think the answer is because life is a winner-take-all game. There's no mercy. If at one time there were many competing forms of life on Earth, the others were driven to extinction because life is competing at a system level for resources -- physical space, sunlight, nutrients, and so on.

As long as different species have different ecological space, they don't compete directly. But species that directly compete face an unstable situation. If there's a complete overlap on their needs and requirements, then one will win and one will lose. For an entire system of life, the requirements are energy, nutrients, and space. Since those are exactly the same requirements of an alternative system, there's a hundred percent competition.

Now, that doesn't prove that alternate life forms couldn't be here. There's been some speculation that there might be a shadow biosphere on Earth, and some people are trying to find traces of that. But so far, they've found nothing.

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