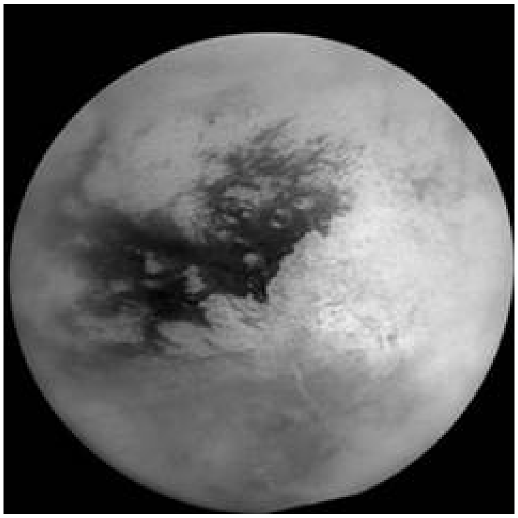
The Living Worlds Hypothesis

September 23 2005



Saturn's moon Titan is enveloped in a thick orange haze, and the organic particles that make up that smog have been raining out of the atmosphere and down onto the surface for millennia. This rich chemical brew is thought to be ripe for life's origin, similar in some aspects to Earth in its earliest days.

Pre-biotic potential aside, a paper recently published in the journal Astrobiology by Dirk Schulze-Makuch and David Grinspoon investigates the possibility for organisms to exist on Titan today. Astrobiology Magazine's Leslie Mullen sat down with David Grinspoon to talk about life on Titan, what sort of food they could be dining on, and how they might make their presence known to us.

Astrobiology Magazine (AM): You recently published a paper investigating the possibility of life on Titan, based on what we know about the moon today.

David Grinspoon (DG): The paper looks at the requirements for life in the most basic sense, and what kind of planets you should look for, and then asks if Titan fits the bill. People have asked that question before, but now that we've had the first Cassini and Huygens results, and Titan's environment is emerging a little more clearly, we thought it would be worth re-examining it.

People talk about Titan and astrobiology all the time, but it tends to be Titan as the laboratory for the pre-biotic Earth. It's got nitrogen, it's got organic chemistry. We've known that for a long time, and that was a large part of the motivation for sending these missions, Cassini and Huygens, to examine the pre-biotic chemistry.

But people haven't talked much about the idea that something might be living on Titan today. I think mostly because it's so cold there, and chemical reactions just proceed too slowly. But Titan turns out to be an exceedingly active planet. We see evidence for cryovolcanism, and for active meteorology. So there's a lot going on there. There are energy sources, flows, gradients, things changing, and different chemicals coming into contact.

I think the most basic requirements for life come down to needing a source of energy of some kind, needing liquids, and needing some basis for complex chemistry. And we conclude that Titan has all three. Obviously it has liquids - if you've got cryovolcanism, you've got liquid reservoirs of water, or water with ammonia antifreeze, near the surface that occasionally is erupting to form those flows. There are also liquid hydrocarbons silting the surface in places.

What's really new in our paper is that we go into the question of energy sources. If there's life there, what's it going to eat? What kind of food is there? And it turns out there's abundant food because of all this photochemistry in the upper atmosphere, where methane is being turned into other organic molecules. Some of those organic molecules are very energy-rich, and one that we consider in the paper is acetylene.

We know it's being made in the atmosphere, we know it's raining down on the surface, and it's been detected at the surface with the Huygens probe. We calculated that, if acetylene is reacting with the hydrogen gas to turn it back into methane, quite a bit of energy is being released. So that's our basis for saying there is something to eat on Titan. We don't know if there are any customers, but there's something on the menu.

AM: So there's acetylene rain from the sky that's produced by the breakdown of methane…

DG: By ultraviolet light and also by interactions with Saturn's magnetosphere. There's a lot of energy up there. Then the acetylene is raining down and getting buried. Then, potentially, subsurface organisms use the acetylene, and in the process reconstitute the methane, which is going back up into the atmosphere.

That's why we called our paper, "Biologically enhanced energy and carbon cycling on Titan," to give this idea that it's part of a cycle. It potentially solves the problem of why there's methane on Titan when we know it's being destroyed.

AM: And the areas of cryovolcanism provide possible havens for life?

DG: You've got to think about where are the places where it would be good to live on Titan. You would be overcoming the cold in part if you go to the hot springs. I like hot springs, and I think that Titan organisms would like them too. I think especially at a place like Titan, hot springs are going to be really nice if you're any kind of a carbon-based life form.

AM: It seems such a world of extremes, because you have acetylene, which makes me think of acetylene torches that make these intensely hot flames, and then you have this frozen world. It's fire and ice.

DG: Acetylene doesn't seem like something you'd want to eat, but on the other hand, the fact that we associate it with acetylene torches is an illustration that there's a lot of energy there. Because Titan is so cold, chemical reactions that we think of as explosive on Earth because they proceed so rapidly might proceed at a moderate pace on Titan.

In order to have life, you want to have chemistry that's not so active that everything's just exploding and burning up, but not so unreactive that it's just sitting there. It's got to be within a certain range. And certain kinds of reactions that on Earth might be too active for biochemistry might be just right on Titan where it's colder.

AM: There's no life on Earth that uses acetylene?

DG: I don't believe there is, but that's not surprising because acetylene is not stable on Earth because of all the oxygen. That combination is explosive, so you don't have acetylene sitting around anywhere. On Titan, there's no free oxygen, so the acetylene could react with hydrogen to create methane.

AM: Your paper also mentioned the chemistry of radicals as another possible source of energy on Titan. I know oxygen radicals are thought to be really bad for life on Earth.

DG: Radicals are very reactive because they're chemicals that are out of electronic balance; they're missing electrons or they have too many electrons, so they're frantically looking around for anything to react with and in the process they can destroy things. We think of radicals as these things that cause cancer, because when you get them in your cells they'll react with anything.

But that very reactivity, if it could be tamed, could be a powerful energy source for biology. One way to tame it might be to exploit it in a cold environment, where the chemistry is going to be much slower. This is separate from the acetylene argument, but we do point out that there are certain kinds of chemistry that could potentially, at the cold temperatures of Titan, proceed at appropriate rates to be good biological energy sources.

AM: I get a sense that there's this whole spectrum of processes in biology, and some of them don't quite work right on Earth - they're too dangerous or energetic - but maybe part of that spectrum could work much better on a different world like Titan.

DG: Exactly. I think that's the way we need to think, because otherwise we're just projecting our own preferences and our own type of life elsewhere. Then we're always going to look for worlds just like the Earth. Maybe that's the only kind of life out there, but I doubt it.

If you think of life in the abstract, as just a controlled chemical reaction that breeds more complexity and then gets to be self-replicating and evolves, then there are probably lots of kinds of life. But you have to think outside the box about what would be the appropriate kinds of chemistry in other environments, and it's harder to do, because you can't just use terrestrial examples.

AM: But at the same time, there might be clues within our own terrestrial examples.

DG: There might well be, and thinking about this kind of thing is valuable because it forces us to consider which aspects of terrestrial life are likely to be universal, and which are peculiar to our own environment. But ultimately we're not going to find the answers to these questions by theorizing and writing papers and making models, we're going to find the answers by going out there and finding it. Science is fun and interesting and worthwhile, but we'll find the answers through exploration.

AM: In searching for life, people often think clues can be found in the isotopes of elements like carbon, since some forms of life on Earth preferentially eat lighter carbon isotopes. But you've said that the isotopic compositions indicative of life are not necessarily going to be the same for Earth and Titan.

DG: You've got to be careful there. I think it's likely that life will result in distinct isotopic signatures, and it's one of the kinds of clues that we should be looking for. At the end of our paper, we list some possible biosigns on Titan, and unusual isotopic fractionation is one of them. But we don't know what kinds of isotopic fractionations alien life will make.

Also, we don't know what other fractionations are naturally occurring on Titan. Gases escaping from the atmosphere fractionates the carbon, but we don't know how much this process affects the isotopes. The problem is not well enough constrained to rule out life, or to prove life at present.

AM: So how does Titan fit in with your idea about living planets?

DG: Cassini saw that Titan has all these processes going on, mixing things up and releasing energy. The main point about the living worlds hypothesis, as I call it, is that planets that are geologically and meteorologically alive are much more likely to be biologically alive as well, especially if they have been continuously active throughout their history. An active surface is not a bio-indicator in the sense that it says, "Ah, there's life here."

But sometime in the future, when we can do comparative astrobiology and we have lots of worlds with life and others that don't have life, I think we're going to find that the ones with life are all active planets.

AM: The phrase "living world" reminds me of something you said before, that "A planet and its life will co-evolve."

DG: Well, on Earth they certainly have. It's not just that Earth is a nice place to live and then life is here and isn't it lucky. Life has made Earth the way it is to a large extent. That's the Gaia hypothesis, and the living worlds hypothesis is closely related to the Gaia hypothesis, just trying to generalize it to other planets.

AM: So life created Earth just as much as it created us, and therefore you might never find another planet exactly like Earth out there. And then I look at Titan, and I wonder whether life could be intertwined with any of the processes there.

DG: I think it's possible. If there is all this energy being released by these powerful chemical reactions, with stuff raining out of the sky like acetylene and other compounds, some of that energy could be going into metabolism, the work that the organisms do to power themselves.

Also, some of that energy is going to be waste heat released into the environment, but in a place like Titan, what we think of as waste heat might not be all that wasteful. Organisms can use it to melt their own little watering holes. Then you can even imagine a sort of Gaian mechanism where organisms are helping to create the environment that helps keep the organisms happy.

Taken to an extreme, you could imagine that this large-scale melting we see on Titan is the result of organisms. I'm not claiming that we can confirm it, but imagine for an instant that Titan is loaded with organisms. I don't think we can rule this out. So imagine life is all over the place, and acetylene and other compounds are being turned back into methane and heat is being released… well, that could end up melting a lot of stuff.

If acetylene is concentrated in certain geologic deposits, which no doubt it will be, maybe there are places where the collective action of that life is melting a lot of stuff and helping to lead to the high degree of activity on the surface. It's pretty "out there" as an idea, but I don't think it's impossible.

If you go back to this living worlds hypothesis and look at a planet like Earth, where life has radically altered the planet, one possibility is that life always radically alters its planet. I think it's quite possible that we won't find life on planets that have not been radically altered by life.

Ref: "Biologically Enhanced Energy and Carbon Cycling on Titan?" Dirk Schulze-Makuch and David H. Grinspoon, Astrobiology (2005), v. 5, n. 4, 560-564.