Astronomy cast Episode 272 for Monday, September 17, 2012: Abiogenesis

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Fraser: Welcome to Astronomy Cast, our weekly facts-based journey through the Cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain; I'm the publisher of *Universe Today*, and with me is Dr. Pamela Gay, a professor at Southern Illinois University – Edwardsville. Hi, Pamela. How are you doing?

Pamela: I'm doing well. How are you doing, Fraser?

Fraser: Doing good...so once again, as always, we are recording this episode of Astronomy Cat as a live Google plus hang-out, so you can join us live on the Google pluses on Monday noon Pacific, 3 Eastern, uhh…18, no, 2000 Greenwich Mean Time?

Pamela: 8:00 pm.

Fraser: 8 p.m. Greenwich Mean Time.

Pamela: Or London Time -- they're not always the same.

Fraser: 8 p.m. London Time, yeah, and then join us live and you can ask us questions, and you can watch us record and you can see how Pamela uses her hands in the recording to show objects rotating, and things flying at the screen, so it's a real treat…and you can also see the episodes on YouTube now as well, so…but it's great to have people join us live. The other thing is we're now doing, I think, four different shows every week on Google plus: so we've got our weekly science hour on Wednesdays, we've got the weekly space hang-outs on Thursdays, we do our virtual star parties on Sunday nights, and then Astronomy Cast on Mondays, so we've got lots of great science and space coverage for you, but we've got a new project to mention this week, Pamela.

Pamela: We do. So over on CosmoQuest, we have what's called Asteroid Mappers, which is a new project that takes data from the Dawn mission -- and this is data that is just released, that isn't available in the planetary data center yet, and so you can be among the very first people to look at images of Vesta, and we're working on creating a map of Vesta, mapping out where the craters are, mapping out where the boulders are, trying to figure out where other interesting geological features are, and so if you want to help out with the NASA Dawn mission science team, we'd invite you to become part of what we're doing over on Asteroid Mappers.

Fraser: So join us on CosmoQuest, and you can actually help define the craters on Vesta, which the scientists will actually incorporate into their research, so I mean, that's it. If you ever wanted to contribute to science, now's your chance. That's really cool, and what I love about this is these are brand new images. People haven't mapped these craters or seen them ever before. These are brand new images raw from the Dawn mission.

Fraser: At the highest resolution so we're not down-sampling anything, or doing anything like that.

Pamela: Yeah that's really exciting.

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Fraser: So the theory of evolution provides a rich explanation for why we see the diversity of life here on Earth. There are so many lines of evidence from genetic drift to the fossil record, but how did life start? How did things go from a collection of raw materials to the building blocks of life, giving evolution and natural selection a way to take over? That first step from non-life to life is called abiogenesis. It's one of the most important questions science will answer. I said "will answer" because I'm really confident that they will eventually get to the bottom of this.

Pamela: Well, you're more confident on this one than I am.

Fraser: Really? OK. Well, we'll see. Right. The point here is that whenever you have a conversation with a creationist, they'll go back to, "Fine. Evolution…fine. I'll give you that we're evolved from monkeys [when really we share a common ancestor with primates], but you take it far back, and it's like -- where did life come from? The theory of evolution can't explain where life came from; therefore, the theory of evolution is nonsense."

Pamela: And the reason I'm doubtful on science solving this one is simply because I'm not convinced that it's a process that happened fast enough to replicate it in a lab, given the current funding cycles of things.

Fraser: So really, if we get…what we need is more money for science, is that what you're saying?

Pamela: And allowing people to apply for funding to do things for many years. The original Miller Uri experiments, those lasted for a couple of weeks, then there was one experiment that basically froze a bunch of different chemicals that they thought would lead to life from 1972 through 1997, so that was a nice long baseline, and they were able to see that over this very long period of time, which was short for geology, there were chemical reactions that took place. We're really going to need to have multi-generational experiments to be able to understand all of the different possibilities.

Fraser: Right, but I mean this is the same argument that's directed at the Big Bang, right, which is, "Well, fine. Your Big Bang explains the rapid expansion of the universe, the motion of the galaxies speeding away from us, the distribution of hydrogen and helium, the comic microwave background radiation, but it doesn't explain what came before the Big Bang; therefore, it's invalid." And that again, is nonsense thinking, right?

Pamela: There are different arguments here. So with the Big Bang we have a theory that we can point to and say our mathematical model creates all these different testable ideas. Let's look at the helium content in non-flooded areas, let's look at the cosmic microwave background…there's all these different things. The problem is we don't have a theory that is that advanced for the origins of life. We don't know if it formed at volcanic vents, we don't know if it formed in clays, we don't know if it formed in ices, we don't know if it formed at the surface of the water, so these are theories at very different levels of advancement, I guess, for lack of a better phrase.

Fraser: Right, but I guess my point is the theory just aims to explain what it aims to explain. It's not trying to explain things that are outside of its scope, so you know the theory of evolution explains the vast diversity of life forms that we find here on Earth, the Big Bang explains the expansion of the universe; it doesn't explain what came before the Big Bang, and the theory of evolution doesn't explain, necessarily, where life originated, only the process that we have that's going on all the time. So that's all, and I think that's just really important. Now, this additional theory of it with evolution that kind of bolts right onto it is to say, "OK, abiogenesis, how did you get from the raw materials: carbon, nitrogen, oxygen, etc. into something that could then self-replicate and go from there?" So let's kind of take this conversation back to the beginning then, and so when did scientists really start to think about this question?

Pamela: It actually in some ways goes all the way back to Aristotle being wrong in the most amazing ways. So Aristotle, like with so many things he put forward, very wrongly assumed that you could think your way into a scientific understanding without going out and making any real scientific data, or observations or experiments, so he along with many others thought that life just naturally spontaneously arose. Leave a piece of meat out and it will spontaneously generate flies, slime will spontaneously generate frogs, dead logs in the bottoms of streams will spontaneously generate alligators, and so there was this notion that life just occurs, and it took a while to get past that one, but in a way, it took getting to the notion that, well, there are microorganisms, there are things that we can't see, there are processes that we need to take note of. You can't see with your eyes, necessarily, that a fly is laying eggs on meat. What you see is a fly on the meat, and then a while later you see maggots, but without the microscope, which didn't come around until the 1600s, you can't get at the fact of "Oh! There's eggs I can't see in that meat."

Fraser: Then there's that classic experiment, right? I forget who it was…they put a piece of meat under a glass jar, and no maggots.

Pamela: There was a whole series of different experiments. Louis Pasteur's were by far the most notable in terms of getting good publicity, where various scientists --Lazzaro Spallanzani, Francesco Redi -- a number of these different individuals demonstrated that if you sterilize something you don't have the same results, if you isolate something, you don't have the same results, and this was extremely important to making that connection of there are things that happen outside of the visible world – the microscopic world – that lead to real-world animals that we do see with our eyes. I mean, it's real-world in both cases, but I guess, "visible-world" critters…

Fraser: Right, and so once you remove the ability for the flies to be able to put in their maggots, then no eggs, no maggots, and the meat doesn't do what you're expecting, although it will still decay, but I mean this is the bacteria that got in there.

Pamela: Well, actually, it won't decay if you don't have any bacteria. Decay requires bacteria. It will just get really dry.

Fraser: Right. Right. So there you go, so now, clearly there's a source of this stuff, so I would guess fast forward and then bring on the germ theory, you know -- tremendous advances in microscopes, and then, you know, starting with, I guess, in the 1900s, Darwin comes up with the theory of evolution, and you know you just start to trace things back, but this leads this inevitable question…

Pamela: That one is actually in the late 1800s, so we're still looking back even further.

Fraser: Oh yeah, 1800s, sorry…so 19th Century, yeah. Right yeah, and so Darwin comes up with the idea of the theory of evolution, but then that leads inexorably to the beginning, which is "Where did the first creature come from if we're all connected?"

Pamela: And the thing I didn't know until I was researching for this show is it was actually Darwin who put forward the idea that, and this really got to me because this is so early in the exploration of electricity, but he put forward the idea that if you mix chemicals, fluids and electricity you have basically Frankenstein's recipe for life, and I just love how everything came together so early on, but we're still working to try and figure out how to reproduce this. And it turns out electricity may not be as useful as Frankenstein's story would purport.

Fraser: Right, but I mean, where was some of the first thinking, or experiments in this process?

Pamela: Well, the earliest ideas were the hot primordial soup notions that is still…you can't really say that there are any leading theories in abiogenesis, but one of the sets of theories is that in the early Earth, where we're still radiating heat left and right, where we're still dealing with a much more active, young sun…back in these early days, our extremely hot ocean that would have had a different acidity than it has today, quite possibly could have been a chemical reaction ground – you can't say breeding ground, you have to say reaction ground – for the types of molecules that could eventually somehow make that switch to becoming self-replicating.

Fraser: Why is that important? I mean, what is the difference between a jumble of chemicals on the ground, and life (or the building blocks of life)?

Pamela: This is one of those things where there's actually no leading theory. It could have been a puddle on the ground that formed life, but I think the reason that people start off with the primordial soup idea is we've all had the experience of: you leave the cup on your table, and you have it filled with fluids on a warm summer day, and well, a few warm summer days later you have something really gross, and this is science.

Fraser: Is that the primordial soup? Mmm…does anybody want some primordial soup for lunch?

Pamela: When you start to think of a large ocean of all the right chemicals mixing and slushing…and the early Earth was a kind of dramatic place. It's thought that during the first billion years or so, we were periodically getting knocked around by sufficiently large asteroids that they released enough energy to evaporate a large portion of the Earth's oceans, and that would in turn lead to, over time, through the greenhouse effect, the entire ocean evaporating, and only as the planet cooled back down from the asteroid's impact energy, the oceans re-condense out of the atmosphere, and so you have this evaporative process that is cycling as we get hit over and over and all sorts of carnage occurring and when you think about it, it's like, "Wow! OK! Crazy stuff happening – life must have emerged from that crazy stuff happening!" We don't really have a solid theory, but that sounds good if you're thinking science fiction.

Fraser: Right, but I know that, for example, amino acids are the building blocks of live as we know it, and you can get to amino acids from this primordial soup, right?

Pamela: Yes, this is one of the many different ways to get to amino acids. One of the things that we're struggling with is it turns out the universe really likes to create amino acids. They're not always stable. Several of them have half-lives of a few years to a few tens of thousands of years depending on the temperatures of the environments they're in, but we find them in space, we find them on Earth, you can create them in a variety of different ways. The original Miller–Urey experiment was able to create over 20 different amino acids by running all of the chemicals needed to create amino acids through a system that included zotting them with electricity, changing the pressures, and so they just like to form. They're carbon molecules -- they do that.

Fraser: Right, but then as the creationists are so happy to say, getting from amino acids to proteins is a whole other world right to RNA to DNA, so what is thought to be that likely step?

Pamela: And this is where, again, many different theories... Some of the ones we're looking at that I think are the more interesting ones are if you take a volcanic rock and you run fluids through it at high temperatures, it actually creates basically sludge, and the sludge that comes out has molecules that are encased in a chemical membrane, and this starts to resemble cellular organisms, and so perhaps there was some way to get from this membraned molecular sludge eventually to something that was somehow self-replicating. We don't know, but one of the processes that allows us to start to get to something that looks like a cell is lava rock plus water given time and heat equals carbon sludge.

Fraser: And we've got other new environments on Earth that have been uncovered, like places like these black smokers at the bottom of the ocean that are great sources of water and heat and time, right?

Pamela: Right, so there you won't actually get the sludge because you're completely encased in water, so that's where the does it happen quickly at the bottom of the ocean, does it happen quickly at the surface of the planet, and that actually dictates when life could have started to form because if life started to form at the bottom of the ocean, that was a much safer place, much earlier than the surface of the planet so you can actually give life a half billion year head start by starting it at the bottom of the ocean.

Fraser: What's really always so fascinating is how quickly life got started. I mean the Earth is 4½ billion years old, but we have evidence of life as old as what about 500 million years to a billion years after the Earth formed, right?

Pamela: We think we're finding life – fossilized bacteria, basically, from roughly 3.9 to 2.4 billion years ago. Trying to date things is always complicated.

Fraser: But, essentially the moment after the Earth cooled down to the point that this kind of thing would be possible, life arose.

Pamela: Yeah. That's pretty much what we think, and so it's just trying to figure out, well, there's always that possibility that it arose at the bottom of the ocean, it arose on the surface of the planet, we could have had multiple points of origin, so this is where we start looking at extremophiles. This is where we start looking at chemical reactions under a variety of different pressures, under a variety of different liquid/lack of liquid. So did life perhaps start in clays, where we end up with different minerologies that start to resemble nanobacteria very closely? It's a fine step between certain…microbes? No, nanobacteria isn't a microbe…between microbes and nanobacteria. It's a very fine line occasionally.

Fraser: But I think one of the other pieces of evidence that we have is we appear to be able to trace all life on Earth back to a common ancestor, that all life is related.

Pamela: Well, all living life.

Fraser: All living life?

Pamela: So you have to remember that there's the methanogens, the critters that respirated methane instead of oxygen. That was a completely different tree of life. So it's unclear, did we get from that to this? Did they have a common ancestor or are they actually two different genesises?

Fraser: Really? I didn't know that! Yeah, OK.

Pamela: We don't always have DNA of the oldest bacteria.

Fraser: Right. Of course, yeah, I mean, 4-billion-year-old bacteria in a rock doesn't really tell you much, but I guess you could have the situation where if life was super common, then you might see multiple genesis (geneses?) on Earth, but it seems like the life that really took off and took over the whole planet does share this common ancestor.

Pamela: It's impossible to know, though, was it simply that life is more efficient and killed off everything else? It's now thought that Homo sapiens, or rather Homo erectus, I'm not sure which, and Neaderthals co-existed and we simply out-competed, so we don't know if it was an out-competition, we don't know if it was a single origin, and so this is where there's a lot of open questions, and because we have plate tectonics, we can't answer everything.

Fraser: Yeah, you can imagine the whole planet being this really fertile environment that life wants to be able to expand into and exploit every single niche once it's got a ready form of energy and fuel source, it's got elements that it can use, it can consume and get rid of, then you can imagine it trying to expand into every possible niche on Earth, which it has. It's evolved. I'm sure it didn't take life that long to expand into every possible niche on the planet in some slime, mold, kind of bacteria way, and so if you had these two life forms that started separately running into each other, one probably would have been better equipped to take over those niches than the other.

Pamela: And…yeah. These are the types of things that we're still trying to figure out. We know that we do find life deep in the soils when we're digging for oil – not we – but when other people are digging for oil, we find it in highly acidic pools of water, we find it in hot springs, we know that certain critters are resistant to radiation, some like living in ice, so life has exploited just about every place on the planet Earth that you have a temperature gradient, and you have something that can be consumed as a nutrient, so as long as those two things are present we seem to be finding life.

Fraser: Now, we're talking about life as we know it, right? Standard carbon-based life forms with DNA and RNA…has there been much thought into life as we don't know it?

Pamela: This is actually a well-timed episode because an article just came out suggesting that we do need to rewrite the tree of life to include some of the macro-viruses, that the largest viruses that are out there actually resemble in many ways the most simplistic DNA-based microbes, so perhaps we simply need to start broadening our thought. There are people who consider broadening things out to start including prions, which are basically proteins that affect the brain, as potentially a life form, and then of course there are the folks who are trying to do things like replace phosphorus with arsenic, replace carbon with silicon, and look for a parallel way of constructing the chemistry of life by just dropping a row down the Periodic Table.

Fraser: And that sounds like it's going to be a pretty fruitful direction to go as well because we're getting to the point now where we're seeing synthetic life forms. I know there was a synthetic virus created just a couple of years ago where they essentially just wrote the…you know they used a DNA printer and they printed out the genetic code of it, and they injected it into a…what was it, a bacteria -- and boom! You had bacteria, right, that roughly matched the same sort of effect of the actual creature, so we're getting to the point now where with DNA splicing and these kinds of things. You just start to run these experiments. You go, "What if we do this? What if we do that?"

Pamela: And it's unclear how fruitful looking for life made out of parallel chemistry is going to be simply because the energies involved aren't the same, the material involved aren't the same, but we are getting better at engineering life -- from inserting vaccines in potatoes to creating glow-in-the-dark cats to a whole variety of different things. We're changing life, and this is…it's fascinating to see how this is also changing science fiction. There was an excellent book, I believe it was called The Wind-Up Girl, by…I can't say his last name. Look up the Hugo award winners from two years ago, and it's a look at the future where we've genetically engineered animals that end up out-competing the wild ones, so we end up losing our planet's genetic diversity because we create these things that take over. We see this happening in North America with invasive species. I know in Europe they've had a problem with mice being an invasive species, porcupines being an invasive species, and it's unclear if we've properly thought through the morals of some of the things we do. There's many nations that are starting to consider, "OK, do we need to take a step back from the genetically-modified plant species that we're distributing?"

Fraser: Now one last question, then, is there's a lot of news, we've been talking about Curiosity quite a bit, we hear where Curiosity is going to be searching for not necessarily life on Mars, but it's going to be searching for the conditions of life to see if…

Pamela: The chemical precursors.

Fraser: Yeah, if the conditions were ever present that life could have arisen on Mars, but you know, we have this also this problem with Panspermia, right? How we've got this situation where even if we do find life on Mars, there's enough rocks traveling between Earth and Mars that, if we find life, it might be related to us.

Pamela: Right, and this is one of those things where it's an open question: "Did life on Earth originate on Earth? Did all life on Earth originate on Earth?" It could be "both" is the correct answer, and the same is true for Mars. We find rocks on the surface of Earth that came here from Mars when Mars got hit by large asteroids, and the debris actually got put into escape velocity and traveled all the way to Earth, and similarly Earth over history has been hit by large rocks that have sent things into space. My favorite Scientific American caption of all time was the extinction of the dinosaurs was created by an asteroid that hit, and then in the caption it says, "Sent rocks, debris and dinosaurs into orbit and beyond." And that would be true is…can you imagine you're the dinosaur there, you're happily munching, you look up you see something shooting through the atmosphere, and you die, but then you get sent into space as a puddle of biological debris?

Fraser: Your parts get sent to Mars to help out the Mars biology, yeah.

Pamela: True!

Fraser: I know, I know, I know, so do you think that we would ever get to the point maybe where we could start to observe life on other planets using some of the techniques that we're learning here on Earth? Could we, you know, using our telescopes?

Pamela: Well, I think observing life is a little bit extreme. I think saying that we can observe atmospheres that are out of chemical equilibrium in ways indicative of life is something we can say. We know that oxygen doesn't naturally occur freely, unbound in atmospheres -- that needs plants. We know that certain chemicals don't occur in certain ratios in the atmosphere unless you have things like humans with Diesel engines, so as we look at other planets, we may see the…unfortunately, the signs of a polluting industrial economy not too different from our own that is destroying the planetary atmosphere in terms of being in natural chemical equilibrium, so that's what we look for is things out of equilibrium.

Fraser: Right. It would suck to be them, but it would be good for science.

Pamela: Hey, we're there, too. We can't really say very much.

Fraser: They can spot us, so we can spot them. Very cool! So last thing and I know this is completely worthless, but why don't…let's come up with a prediction here, so I'm a total optimist and I actually think that science will crack this, not…within the next, I'm going to say, decades – two decades. How about you?

Pamela: See, I think we're going to be able to say life is common, either by finding it or not finding it, on other rocky bodies in our solar system. I think answering the question of: "Did it originate on land or at sea?" Paul Revere had a much easier job than the biologists do.

Fraser: Yeah, I mean, you want to get to that point where they can just kind of go, Zap! And Boom! There's life. And Zap! Again, there's life.

Pamela: And I think it was probably a process that would take so long that there's just not going to be the patience within the funding cycle.

Fraser: Right, but I love the fact that you were able to sneak in a "we should fund science" advertisement right into this podcast.

Pamela: Well, we need to fund things that are longer than four years for science.

Fraser: Yeah. Alright, well a wonderful conversation as always, Pamela. Thank you very much for joining me this week, and we'll see you next week.

Pamela: Thank you. It's been my pleasure.