07-09-04 Panspermia
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Special Episode: Panspermia

As a reward to the all the dedicated fans who completed our demographic survey, we released this special episode of Astronomy Cast. As promised, we're now releasing this episode to all of our subscribers. Panspermia is a controversial theory that life on Earth originated… out there. Maybe it started out in a cosmic dust cloud or originated from another planet, but somehow the very first lifeforms made the trip through the vacuum of space and colonized our home planet.

**Fraser Cain**: Hey Pamela

**Dr. Pamela Gay**: Hey Fraser! How's it going?

**Fraser**: Good. Well, I'm not going to give any current events because people will listen to this episode at various times and so whatever's happening in our lives could be totally out of date or could be happening right now.

All right. If you're listening to this special show, it means you found out the URL to this secret location. You filled out a survey form and helped us gather some demographic information. We promise we won't use this to abuse your personal privacy. We just need it to fine tune the show; we can present our show in front of potential sponsors, as well as apply for some educational grants. So this is all for the best.

If you somehow got this episode and you didn't fill out that form, please go back, find it, and fill it out so that we can gather that additional information. There's a link to the form on our homepage so that's how you can access it for now.

All right, now onto your reward.

Evidence is clear that all life on Earth is connected at a genetic level. Everything is related. Now you might not want to admit, but you and every other form of life on Earth share a common ancestor right back to that first little critter that got everything started. But the question is, did life start here on Earth, or did it arrive from space. Are we all aliens?

Today's episode is about panspermia. So Pamela, why don't we sorta go back to the beginning and talk about what the concept of panspermia is.

**Dr. Pamela Gay**: Well the basic idea is that perhaps life here actually did, as they say in Battlestar Galactica, start somewhere out there, out there among the stars. And somehow it managed to find its way to the planet Earth. Perhaps it was carried here on an asteroid. Perhaps it was carried here by a comet. Somehow, life from another world hitched a ride and crashed into the surface of our planet and then proceeded to thrive and slowly evolve and change until we ended up with the diversity that ranges from mosquitoes to platypuses to human beings to all sorts of weird things that live in every possible niche within our planet's environment.

**Fraser**: Now where did this theory first come from?

**Pamela**: Well it's hard to identify exactly who came up with it first. One of the oldest names that I've been able to identify with it is actually Lord Kelvin. His idea was, perhaps life started somewhere out among the stars and was carried here to the planet Earth. In general more modern theories of panspermia often look to the planet Mars which earlier in the solar system's evolution and the planet Earth was warm and possibly comfortable for life. Our planet was a little too warm initially. And so people often wonder, when we talk about panspermia, "Well did perhaps life begin on Mars and then die there and pick up again here?"

**Fraser**: Space travel for humans is so difficult. You know, we head out into space and we die right away. So how is it possible that life could get, could handle space travel without you know, a space agency to develop spacesuits and rocket ships and all that kinda stuff.

**Pamela**: Well, human life is fairly fragile. Fragile's an understatement. But there's other types of life that really, it can shut down and be Ok. For instance, the European Space Agency took a bunch of lichens, uh, not moss, but that's the closest thing I can think of to describe it. It's this green stuff that often grows on the sides of rocks.

**Fraser**: Right. I know the stuff. Yeah, you'll see it sort of on one side of the rocks. You kinda scrape it off. It's like brownie green dusty…

**Pamela**: …Yucky stuff…

**Fraser**: …Yeah.

**Pamela**: So they took a bunch of lichens up into outer space, exposed them to the vacuum, the radiation, the extreme cold, the extreme hot of space, brought them back down to Earth, and they thrived.

**Fraser**: And so this wasn't an environment they necessarily evolved in It was just something that they'd never even been exposed to and yet they did fine in the vacuum and radiation of space.

**Pamela**: Yeah. They were exposed for a total of almost fifteen days back in 2005, went up, orbited around, came back down, and then continued to grow normally. So, with the lichens, it was possible for it to survive, even having gone through this terrible terrible experience. And it's not the only example.

One of the lunar probes, Surveyor, went up and it carried with it some hitchhikers. There were some normal bacteria that had gotten onto the little probe. Somehow someone sneezed, someone didn't wash their hands properly, someone was eating in the clean room, who knows. It ended up with bacteria on it. And during the Apollo 12 mission, the astronauts rescued a few pieces of Surveyor and brought it back down to the planet Earth. And it was found that the bacteria that had hitched a ride to the Moon was still viable. It was still capable of reproducing and creating new bacteria.

**Fraser**: So the bacteria had landed on the Moon as part of the Surveyor mission, sat there for several years, right?

**Pamela**: Uh hmm.

**Fraser**: And the Apollo astronauts grabbed… I know they grabbed like the camera or some parts of it, took it in their spaceship, brought it back, and the bacteria did not even bat an eye.

And once again, this is not like bacteria evolved occasionally having to live in the vacuum of space. It just was a brand new environment and yet it was able to handle it. So why are these kinds of lifeforms able to handle the most extreme environment there is?

**Pamela**: Well some lifeforms have the ability to shut down completely. They'll have all of the water in their cells leave and oftentimes they'll inject some sort of a different chemical compound into the cells. Uh, a sugar or something else to prevent the cells from getting damaged from these less than optimum environments. They'll often curl up or coat themselves in something to protect themselves. And then when they're exposed to water, re-exposed to more optimal temperatures, sunlight, things like that they'll come back to life. So they're able to just shut down, go into suspended animation.

If you've ever watched a SciFi show where they show humans going into suspended animation, they always have tubes and fluids and cooling and all this other sort of crazy stuff. Well, that's because humans don't create the stuff necessary to have their cells get frozen and not explode or something else traumatic and life ending. They hook us up to chemicals that these little bacteria are able to create completely on their own. These little critters create their own suspended animation cell.

**Fraser**: So let's talk through the process maybe that life could get from planet to planet here in the solar system. What would happen? What would the process?

**Pamela**: Well, from Mars to Earth it's a fairly easy process. We've actually found numerous rocks from Mars here on the planet Earth. During the early pasts of the solar system there is a period called the age of heavy bombardment. Basically the meteors hadn't figured out where they wanted to be yet so they were nailing everything in the solar system. Earth was getting hit; Mars was getting hit; moons were getting hit; everything was getting hit. And if you throw a large enough object at Mars, which is a fairly low gravity planet, it's a lot smaller than Earth, when say a kilometer across, a mile across asteroid hits Mars, it not only creates a big crater, but it also splashes rocks up into the air and not just into the air but out of the planet's gravity well entirely.

**Fraser**: So an asteroid can hit Mars hard enough to throw debris into orbit or even out of orbit right out into the solar system.

**Pamela**: And because Mars orbit and the Earth's orbit do have certain key places that have us lined up such that something can very easily go from Mars to Earth and vice versa. It's possible to hit Mars, have a rock get thrown up into just the right elliptical orbit that a little while later it nails the planet Earth.

**Fraser**: Asteroid hits Mars, knocks out debris, the debris floats around in space for some unknown mount of time, and then it re-enters the atmosphere and lands on the planet.

Fine. Bacteria, lichen they can handle being in space for a little while. But being part of an asteroid impact on Mars and then re-entering the Earth's atmosphere has got to be extreme environments. How can they survive that?

**Pamela**: Well there's actually been some really neat modeling done to answer exactly that question. Why aren't these critters roasted? Squished? Something like that? And it turns out that there is a certain region in the dirt, in the soil around the impact zone where the shock waves from the impact propagating outwards and reflecting back inwards basically cancel each other out.

So the net force experience by some poor rock that has bacteria living in it is straight up. So the rock only gets shot into space, and it doesn't get squished or melted or anything like that in the process except by frictional forces of getting launched. If you have a really good big rock as it goes up through the atmosphere it is going to get heated up, but it is the outer shell of the rock that is going to get melted and other such traumatic thing and the inside of the rock is just going to get hot and these bacteria know how to survive stuff like that in some cases.

**Fraser**: Ok. So that's the trip up. Now what about the trip down?

**Pamela**: Well, what goes up has to come down maybe if it gets too close to another gravitational well. And again, it's the outside of the rock that's now going to get progressively smaller as it comes through the Earth's atmosphere so the outer parts of the rock get hot, get burned off into the atmosphere, but the very center of that rock may still be a safe place for bacteria and microbes to be.

**Fraser**: I've actually heard that asteroids come down to Earth you know meteorites will land and even though the outside might be hot, the inside is actually freezing cold.

**Pamela**: It's sort of the problem of you forget to thaw your turkey ahead of time. You take a completely frozen turkey; stick it in a 500-degree oven; you're going to burn the outside of it and the center is still going to be ice eight hours later. So you take one of these asteroids that's out in space so it might be a couple of hundred degrees below zero;

it might even be colder than that. And the trip through the atmosphere isn't long enough for the heat to propagate all the way into the center of the asteroid.

**Fraser**: And there's no question that we've found asteroids from, or meteorites from other planets in the solar system and even the Moon, right?

**Pamela**: Right. We've identified several different rocks that we know pretty much for certain came from Mars.

**Fraser**: How can we know that for certain?

**Pamela**: They don't have the correct chemical composition to be from just an asteroid. The way we know this is asteroids pretty much formed where they are. They're left over debris that failed to make itself into a planet. Whereas on Earth we have rocks that have undone geologic things. They've been rained on; they've been spit out of volcanoes; they experienced weathering. The rocks that we're pretty sure came from Mars appear to have been formed through the volcanic processes. Magma. And the composition of gases that get trapped in the rock, because as rocks form they have air around them and that air is representative of whatever atmosphere the rock formed in. So the air trapped inside the rock is representative of Mars atmosphere.

So we have a rock that formed in volcanic processes, which isn't how asteroids formed, so we had to identify, so Ok, where do we know there are volcanoes. Well, there's different moons. Like the Moon of Jupiter Io has lots of volcanoes. Uh, Mars had volcanoes. We think Venus had volcanoes.

Then we look at what are the gasses trapped inside air pockets in the rock and the gasses trapped in the rock match Mars.

**Fraser**: That's amazing. So some rock that formed in a volcano on Mars, trapped little pieces of the Martian atmosphere, was then blown off the planet, and landed here.

**Pamela**: That's a rock that had a traumatic life.

**Fraser**: No kidding! [laughter] We get the sense that these rocks could be landing on Earth from Mars and other places. Could this process be happening across star systems?

**Pamela**: There's been simulations to do that, to try and figure out well, what is the probability. The person doing the work is Jamie Loche. He did what is called a Monte Carlo Simulation. This basically where you tell your computer try everything. And you define everything mathematically. Try all the values from this to this. Try all the speeds from this to this. And see if you can get a rock from, say the planet Earth, out into the solar system, and then to leave the solar system. He ran the simulation over 4.6 billion years, and over 4.6 billion years only one or two chunks of rock managed to escape our solar system. It's not a zero probability, but it's pretty close to zero.

**Fraser**: But if you multiply that by the number of stars in the galaxy, you've got hundreds of billions of stars and each one of those could be putting out some number of rocks over the course of its lifetime.

**Pamela**: But all he asked was, "How many rocks are escaping?" So now we have to add in the probability that it's a rock containing life that's capable of existing frozen in space, not just for a few days, not just for a few decades, but now for millions of years.

Yes, we do occasionally find seeds from the Egyptians and the ancient pharaohs that we can still get the seeds to germinate in labs. We do still get mammoth meat that has viable DNA in it. But now we've talking over just the course of human lifetimes we're able to find things that within the fairly reasonable atmosphere of our planet Earth are able to survive.

But we're talking about taking a microbe, sticking it in space for billions of years, and asking it to land on a world that isn't optimal for it necessarily, survive, propagate, and fill the planet with new life.

**Fraser**: So then are there any other, I mean we've talked about this asteroid's shuffling rocks around in the solar system. Are there any other ways, perhaps, that life could propagate from planet to planet that is not just rocks?

**Pamela**: Well, there's always the question of where are the places that life could form that in ways that we don't necessarily think about. One of the neatest, but not easy to figure out what to do with pieces of knowledge that we've found is space is filled with amino acids. Amino acids form very naturally. And so you can look at a giant cloud of gas and dust in the middle of nothing and it's got amino acids. These are the building blocks of life.

What if somehow these amino acids were able to form life in the clouds of Venus? What if they were able to form life in the ice fields of Enceladus and that life is getting sent into space with the geysers? Now, this is life that could perhaps could hitch on a comet. This is life that might find some other way other than a flying rock to get to us.

**Fraser**: So, couldn't some of this material just get shoved outside of the solar system by the solar wind?

**Pamela**: Yes, it could. But you have to ask what are the other options? So you have Enceladus going around Saturn and it's spewing off stuff with geysers. We don't know if there's life. We just know that there's fluids getting shot into space. And some of those fluids are probably gonna end up crystallizing into ice getting gravitationally sucked back down into Saturn. Some of it is going to get incorporated into the rings, get scooped up by the gravity of other moons. Some of it is going to escape the gravity well of Saturn altogether and start its way out of its way out of the solar system being pushed slowly by the solar winds.

But as its leaving the solar system it could collide with Kuiper Belt objects, with Oort Cloud objects that eventually turn into comets.  It's all low probability.  Everything is low probability.  We're dealing with very much fantasy land here.  But one thing the fact that we have life here on Earth has taught us is that in some cases the improbable still happens.  Life still finds a way to form and make its way into a useful environment.

**Fraser**: You talked about how we look out into space and see amino acids everywhere. Is it possible then that life could be forming or the building blocks of life are forming in these clouds and then its raining down on potential habitable worlds?

**Pamela**: Well, one of the problems with the interstellar media is its not dense.  The average vacuum that I can create a teaching lab that is good at blowing up balloons that don't appear to have any air in them is less of a vacuum than many interstellar clouds.  So you compare interstellar cloud, filled with amino acids, vacuum in lab, the cloud isn't as dense.  The atoms and molecules in these interstellar clouds, the amino acids in this interstellar medium, they aren't colliding with each other very much.  They're not interacting with one another very much.  And in the ways that we're coming up with that life could have started getting the chemical to squish themselves together and do neat chemical reactions is one of the ways that that we think things needed to happen.  So the environments of the interstellar medium just aren't dense enough for life as we think we might understand it to have been able to form.

**Fraser**: Now there was some recent research just in the last week, of when we were recording this, a new research on ways that life could be as we don't know it and what kind of an impact could that have on the possibility of life moving from planet to planet?

**Pamela**: Well, it affects the places that we consider reasonable to look for life.  For instance life here on the planet Earth is all reliant on there being some sort of a temperature gradient and water being present.  So you need chemical reactions going that are gonna generate energy.  We can either have sunlight hitting a leaf that causes things to happen inside the leaf that end up creating photosynthesis that leads to sugars that the plant needs to survive.  Or we can have down in the deep sea vents chemical reactions going on in the thermal gradient that lead to all sorts of giant clams and sea cucumbers and things being able to survive in this pitch-black absolutely no sunlight at all type of environment.  But in every case we have water and we have a temperature gradient.

As people start thinking about, "how could life exist", we realize water is a great solvent, and that's part of what makes it useful for life.  But there are other solvents out there. There are other fluids in our solar system that might make life possible.

There's sulphuric acid which if we're going to be looking for life on planets like Mercury and Venus might be the solvent necessary for life.  There's methane where when we look at Titan, Titan has liquid methane.  That might be another place that life could exist. There's liquid nitrogen out on the outer planets Uranus and Neptune  Liquid nitrogen again might be another solvent that works in a different temperature regime to allow super cold life to exist on these super cold planets.

**Fraser**: So our definitions of life have to change and so the kinds of places where life could form have to change and so the mechanisms for transporting life from planet to planet and system to system have to change as well.

**Pamela**: Well we still have to have some mechanism to get things from A to B which means we need a transport vehicle. So I think we're consistently looking at things like rocks and comets to get things from point A to point B. But the types of things that are capable of hitching a ride are increasing in number and variety as we use our imaginations.

Just DNA itself may not be required. Life that has formed naturally on the planet Earth all relies on four different amino acids to form DNA. But scientists in labs have been able to create, engineer, life that has six different amino acids instead. We've been able to re-formulate DNA. It's possible that DNA takes different forms. It's also possible that perhaps DNA isn't the only way to do it. Maybe lifeforms as we do not know them are able to encode genetic information in just proteins instead of using just amino acids.

**Fraser**: And I've actually heard an interesting piece of research someone saying that one of the most expensive way to communicate, or extraterrestrials if they wanted to communicate with us is actually be with atoms. That it is so expensive to send out broadcast signals across interstellar space that it would actually might be more efficient to send out probes, messages, carved on a rock, or, you know, a CD. [laughter]

And same thing. You could, you know, if you were an alien, and you wanted to colonize the galaxy, one of the most effective ways to do it might be just to send out packages, you know, instead of waiting for meteorites to do your work, you actually just send out a package with life ready to go targeted at stars specifically. It could get there a lot more quickly.

**Pamela**: And in a way we might have already done this. The Voyage I and II probes each carried information about the planet Earth and there's a non-zero probability those things still have some of our own viruses, bacteria, microbes somewhere imbedded in the capsules. So perhaps we've done that ourselves.

And one really recent way new way to carry information was put to use by the Japanese who actually came up with a way of using the four amino acids to build a code and inscribe in the DNA of a bacteria $E=MC^2$. So we're now starting to store information in genetic structure of little tiny critters.

**Fraser**: Well, I guess the Earth might not be our Home Sweet Home after all. [laughter]

All right. Well, thanks Pamela. That was great. And I hope those of you who filled out the survey got your money's worth. Thank you very much for all your help. We really appreciate it. Now back to the regular episodes scheduled.

**Pamela**: Thanks again for all your help and thanks for listening.