Ask A Biologist Vol 089 (Guest Nick Lane)

Why Is Life the Way It Is?

Life on Earth is tied to carbon and water, but would this be the same for life forms that evolved on other worlds? This is just one of many questions that Biochemist and author Nick Lane talks about while visiting with Dr. Biology. Listen in as Nick explores not only life on our Earth, but also what it might be like on other planets. Nick also reads from his book, *The Vital Question*, and weighs in on the question of viruses - are they living or non-living?

Transcript

Dr. Biology: This is "Ask a Biologist," a program about the living world, and I'm Dr. Biology. For our topic today, we're going to tackle the simple question of life. I know it's not such a simple question. In fact, it often gathers more questions than answers when you start studying living things.

Take, for example, the question my guest posed, as part of his recent lecture for the Beyond Center at ASU. The question was, "would life on other planets be anything like us?" Joining me today is biochemist and author, Nick Lane. He holds the position of Reader in Evolutionary Biochemistry in the Department of Genetics, Evolution and Environment at University College London.

Nick also leads the Research Frontiers Origins of Life program, and is a founding member of the Consortium for Mitochondrial Research, also at University College London. Along with his research, Nick has authored a collection of popular science books including his recent publication, *The Vital Question: Why is Life the Way it Is?*

Nick Lane, thank you very much for taking time out to join me on Ask a Biologist.

Nick Lane: My pleasure, thank you.

Dr. Biology: Let's start off with what I was talking about at the beginning of the show and the full title is "The sex of aliens." Would life on other planets be anything like us? So the question is, would it?

Nick: Well, I think it would, but at least in a superficial way it might not, but in a deeper way I think it would be very similar to us. We can imagine all kinds of weird aliens, but whether they behave like us, whether they communicate in a similar way, whether they are sexual, whether they have two different sexes.

Those kinds of questions are the ones that we see that on Earth. We look at plants, plants have two different sexes, some fungi have 10,000 different sexes, and we can't understand really what's going on there at all, but most of them still have really only two sexes.

There are these themes that we see in life on Earth, and the question is why would we see something similar on other planets?

Dr. Biology: For example, anybody who spent much time with Ask a Biologist or in the world of biology knows we are carbon-based.

Nick: Yeah.

Dr. Biology: Would life on other planets be carbon-based?

Nick: I think it would be, yes, almost certainly, not necessarily every time. You could say that this is a lack of imagination that we can't imagine as we are Earth-bound biologists, we see everything around us is made of carbon, so we think life elsewhere has to be made of carbon. That may seem like a real lack of imagination.

If you think about why carbon is good, there is some really good reasons why life here is made of carbon. One of them is its really common. You get carbon just about everywhere in the universe, far more common than silicon.

It might not seem like that way on Earth with all these rocks around us and life seems like a small part of that, but actually there's more carbon even here than there is silicon. That's one thing, it's really common.

Another one is it's really good at its job. It forms strong bonds with other atoms and it can make really large molecules, like DNA, the genetic code, which is an enormously long molecule. You can never do anything like that with silicon or any other atom that we know about.

Dr. Biology: Let me just interject here, that DNA, one of the interesting things about Deoxyribonucleic acid, it's such a mouthful, we always change it down to DNA. That's the blueprint and instruction set for all living things and that's impressive.

Nick: It's one of those things that you think, "Would life somewhere else have something like DNA or would it be completely different?" We don't know, is the simple answer to that. DNA is really good at what it does, it's an incredibly stable molecule.

There's other molecules as well, which are a bit like DNA, we call it RNA, that stands for Ribonucleic acid, it's one atom different. That's practically it, it's one oxygen atom is extra in the RNA, compared to DNA. Instead of forming this long double helix, which is amazingly stable and which can code for a human being, it forms these contorted, twisted up little molecules that are far more reactive and unstable.

They can code for a virus like the HIV virus that causes AIDS, but nothing bigger or more complex than that. DNA is really good at what it does. It wouldn't be very surprising if, on other planets, we found something, if not exactly the same, at least quite similar.

Dr. Biology: All right. We've got carbon and very likely it's out there in these alien worlds. What about water?

Nick: It's a strange thing, but we don't know why water is so important, or even if it is important. Most biologists think that it probably is important. I remember going to a conference at the Royal Society in London. It was three days long and it was about, "Why does life use water?"

At the end of three days of all these biologists and chemists arguing with each other, the answer was, "We don't know." [laughs] We really don't know, but one thing that we can say is that it's really common, again. You find it right across the universe.

The other thing is it does have some amazing properties and those amazing properties, very few other molecules have the same properties. Carbon compounds, if life needs carbon, these carbon compounds, some of them dissolve, some of them make membranes, and interesting shapes and structures in the water.

The combination of those two things, it works really well.

Dr. Biology: You talked about membranes and if we talk about those, then we're going to be talking about cells. We often talk about cells as the smallest unit of life and all cells will have some form of a membrane. We have these membranes, we have cells. Do we have to have cells to have life?

Nick: You can imagine life that doesn't have cells. Viruses are not cells, but they can't replicate themselves unless they infect a cell, and then they use all the machinery in the cell to make copies of themselves.

Then there all kinds of other weird things like jumping genes for example, where they're actually called retrotransposons, but the jumping genes is a much better term. They would jump around literally, they copy themselves and right across the whole genre all of the DNA of a cell, they can hop around and make copies of themselves.

All their life is hard to say, but they need a cell to operate in. Yes, life really does need cells certainly, from life on earth everything that we know that we could say that's a life for sure is a cell.

Dr. Biology: I introduced you as a biochemist at the beginning of the show -- and that's I would say I don't know if you know I'm going to say this, but this is going to be your day job, [laughs] -- but you are also an author of multiple books, and the latest one is called The Vital Question: Why is Life the Way it Is?

Nick: That was the English subtitle, "Why is Life the Way it is." The American subtitle is more descriptive and that was, "Energy, Evolution, and the Origins of Complex Life." That's a slightly different title.

Dr. Biology: Why is life the way it is?

Nick: It comes down to energy, I think. There's no agreements about these questions in science. That's one of the great things about science is that people disagree with each other, and those disagreements are based on knowledge, and they are based on experiments, and they are based on changing your mind as you find out more information and you learn things.

Every good scientist should be willing and ready to change their mind when facts no longer support what they think.

What I think is that energy is not exactly forgotten, but we spend so long thinking about genes and information for very understandable reasons, because we get so much information from genes. It's such a good way of looking at how life evolved and came to be as it is that we've almost forgotten that cells are more than just the genes.

One of the most important things about cells is the way that they get the energy to make copies of themselves at all. To make all these proteins, and all the DNA, and all the membranes that make up a cell. All the parts of a cell, it all needs energy. Every time a cell divides in two to make daughter cells, it needs energy all the time.

The strange thing is that it's not just any all kind of energy is a kind of a force field around the cell, is an electrical charge which is amazingly strong. It's like the same strength is a bolt of lightning is a 13 million volts per meter is the strength.

If you were to shrink yourself down to the size of a molecule really tiny, then that's the strength that you would feel if you were next to the force field that surrounds just a bacterial cell.

Dr. Biology: The moral of the story is if you shrink down you better be ready.

Nick: [laughs] You're going to get zapped.

Dr. Biology: Because I brought up the book, part of the reason is because I have the book here.

Nick: Thank you.

Dr. Biology: I was hoping I could get you to read one section.

Nick: Sure. Do you have a section in mind?

Dr. Biology: I do. I have one paragraph and I'd like you to read. Once you're finished, I think you'll see why I brought it up, because this is one of the most popular questions that comes in to Ask a Biologist.

Nick: "It is a cold killer with a calculated cunning hold of a million generations. It can interfere with the sophisticated immune surveillance machinery of an organism, melting unobtrusively into the background like a double agent."

"It can recognize proteins on the cells surface and lock onto them as if it were an insider gaining entrance to the inner sanctum. It can home in unerringly on the nucleus and incorporate itself into a host cells, DNA. Sometimes it remains there in hiding for years invisible to all around."

"On other occasions, it takes over without delay sabotaging the host cells biochemical machinery, making thousands upon thousands of copies of itself. It dresses up these copies in a camouflaged tunic of lipids and proteins, ships them to the surface, and bursts out to begin another round of guile and destruction."

"It can kill a human being cell by cell, person by person in devastating epidemics or dissolve an entire oceanic blue moons extending over hundreds of miles, overnight. Yet most biologists would not even classify it as alive. The virus itself doesn't care."

Dr. Biology: [laughs] All right. Now, that's the theme -- viruses, living or non-living?

Nick: I think they are living and I used to think that they weren't living. I've changed my mind on that one. The reason that people can't agree about it is that viruses don't have a metabolism of their own, they can't produce energy of their own and they can't make copies of themselves, except when they take over another cell.

Any definition of life, and there's lots and lots of really bad definitions of life no one can agree about a good definition of life, but almost every one includes metabolism activity, some ability to convert raw materials in the environment into energy to make copies of yourself, and viruses can't do that.

From that point of view, it seems as if they're are not living, and yet you see pictures of these things. They're like a unilateral or something, they are amazing structures that they look designed -- and designed is a bad word in biology -- but is also a key in biology, because life looks so designed and viruses look designed in the same way.

There doesn't have to be a designer they just look designed. The question is how do they get to be that way if they're not alive? The other thing about viruses is that they behave really maliciously.

They look as if they've got it in for whatever cell it is that they are attacking, and they behave with an incredible ingenuity. Again, that's a trait of life, it's difficult to say that this is a definition it's just they look, they smell alive to us as biologists. I don't know what you think, do you think viruses are alive?

Dr. Biology: I'm one of those that the way I classify it is when they're outside of a cell they're just a complex molecule, and I just don't consider them living, but once they get inside the cell then of course, they're fully armed and then I do say, "They're living."

So I'm kind of skirting the issue here, because I'm saying outside the cell you're a complex molecule, inside the cell, yes, you have one of the most important traits and that's being able to replicate yourself.

Nick: Now, the reason I think that I would describe them as alive is that they are exploiting their environment to make copies of themselves, and that's what all life does. Even plants, they need water, and they need carbon dioxide from the air, and they need full tons of light from the sun, they need those things. If you deprive them of those things they're going to die.

We need to eat, we need to breathe, and so we all exploit the environment around us. The more complex an organism is, the simpler the environment can be that it exploits. We don't need very much beyond food and oxygen because we're already very complex. Plants need even less, because in their biochemistry, in their cells they're even more complex than we are.

Viruses are incredibly simple, but they exploit in amazingly complex environment. They exploit the insides of other cells. They're exploiting their environment. They're using it to make copies of themselves.

If you think of life as the ability to make copies of yourself by exploiting the environment then viruses are alive by that definition.

Dr. Biology: OK, so once I'm inside a cell I'm going to agree with you.

[laughter]

Dr. Biology: Now, speaking of viruses and cells, which came first?

Nick: Nobody knows, I think they could have arisen at about the same time. In fact, there's a problem if you're not a cell which is that what tends to happen is that if you've got things like viruses.

If you've got effectively, let's call them living things, let's imagine that they're living things, or they're just bits of DNA, or bits of code, and all they want to do is make copies of themselves, they don't care about anything else, they just want to churn out furious copy after copy after copy.

The problem is that it's the fastest replicators that always win. The ones which are a bit smaller and a bit simpler tend to make more copies of themselves, and those slightly bigger ones which are slower are more rebellious.

Any system which doesn't have cells in tends to die out, because the parasites take over and they copy themselves until they've exploited all the resources, and then everything dies and that's the end. It's a very, very unstable system.

What cells do is they trap these replicators inside the same space so their fate is linked. As soon as their fate is linked then one which specializes to say, "OK, I'm going to do this thing for the cell as a whole, and another one does something else for the cell as a whole."

Then together by collaborating because their fate is shared, and they are able to begin to encode things other than replication speed, they can begin to convert the environment into copies of a cell, and that's metabolism, that's the beginning of metabolism.

You need a cell for metabolism, and so really for life, the cell has to come first.

Dr. Biology: We're talking about viruses and so this gets us into the immune system. On Ask a Biologist, we have a really fun comic book actually out there called "Viral Attack."

It's a great way to learn about the roles of the different cells, because there are cells specifically in our body that are trained to seek out and destroy viruses, also bacteria, bad bacteria. I always have to be careful about that because people just think all bacteria are bad.

Nick: All bacteria are bad.

Dr. Biology: Actually, we wouldn't be alive without bacteria. With that said, I'm really curious about the role of the cells themselves in complex organisms, and how they've learned to basically defend against these invaders.

Nick: They do it by recognizing them and that's an amazing feat, because what they do is they combine different bits and pieces of genes together.

By doing that they're able to come up with an amazing array of billions and billions of different types of protein that are able to recognize, so almost any bacterial, or any virus, or anything which has got a protein the immune system is able to come up with something which is going to recognize it, and bind to it, and activate that immune cell.

When an immune cell recognizes a bit of a virus, a bit of a protein on the surface of the virus then it activates the whole cell, and that cell then makes copies and copies of itself, and they will target that virus and try to break it down.

Dr. Biology: The other thing we've done today is that were the role of the vaccine is basically to build up those cells...

Nick: Exactly.

Dr. Biology: ...and basically get them knowing the most wanted list. Right? You can imagine the poster -- the wanted poster. We basically jumpstart that so they don't have to learn and build up that army of cells that can attack those viruses they're ready to go, for example, the flu vaccine we get every year. The question is why do we have to keep getting different ones?

Nick: That's because the flu itself keeps on changing, it keeps mutating and evolving, and changing its proteins, and then it's doing that all the time. We can't stop that happening, that's evolution. In fact, this is probably from our own lives point of view this is the easiest way to see evolution in action is how viruses change, and they change really quickly.

In the space of a few years, the viruses have changed almost beyond belief.

Dr. Biology: Even the cold virus, you say the common cold it's not that common.

Nick: [laughs]

Dr. Biology: There are a lot of viruses out there that are all classified as a cold. If there was common and simple, we probably would have something that would help us battle these colds when we get them -- speaking of which I have one today. [laughs]

Nick: Mm-hmm.

Dr. Biology: While we're in the cell, there's an area that I know that's near and dear to you, inside a cell we have lots of parts and they're called organelles which means tiny organs. There's one in particular called the mitochondria and when you're learning about the cell, one of the neat things about the mitochondria, it's basically the powerhouse. That's back to your energy story, right?

Nick: Exactly, yes.

Dr. Biology: But the mitochondria wasn't always in the cell.

Nick: No. The mitochondria were cells themselves once. They were bacteria. We know this because they still have some of their own DNA, some of their own genes and coding bits and pieces of information about how do you generate energy right there on the spot.

They still behave in some ways a little bit like bacteria. When they divide themselves in half, they do it pretty much the same way the bacteria do as well. These antibiotics can affect all mitochondria, too, for the same reason that they affect bacteria.

We know that they were bacteria once, but we don't know exactly what was going on because this was two billion years ago. Again, in science, there are arguments about everything. Eventually, we'll come to an answer that people can agree is the right kind of answer, even if it's not exactly correct.

At the moment, we're still in the midst of -- let's call it a power struggle because these are the powerhouses of the cells. We don't know exactly what kind of bacteria they were. That matters because they had a relationship with another type of cell, which was our own type of cell that acquired these bacteria.

We don't agree among ourselves what kind of a cell that was either. It could have been really simple. I think it was really simple, very much like another bacterium. Other people think it was already quite a complex cell.

It may sound trivial, but the difference is quite important because if it was already a complex cell, then that means it could do a lot of evolution without all the energy needed. The people who think that it was a complex cell already think that evolution is going to happen. The energy doesn't matter very much because it's a small part of the overall picture. It's the genes that really matter.

I see the other way around to that because the thing which is really fascinating is that bacteria just stayed bacterial. They arose four billion years ago. That's an incomprehensible amount of time.

If you look at the bacteria from four billion years ago and you look at the bacteria today, it's the same. In their appearance, they are tiny. They're morphologically very simple. In their biochemistry, they're complex, but in their appearance, they're really simple.

They don't have any tendency to become large and complex and turn into a human being or something. I think that the key moment was when we acquired the bacteria that became our mitochondria. That gave our type of cell, we call them eukaryotic cell. That just means a true kernel. A kernel is the nucleus where we put all our DNA, like the heart of the cell.

When we acquired the mitochondria, we got so much energy with that because what we did really was we had lots and lots of powerhouses internalized, all of which became very specialized just to produce energy for this cell. We could swell up in the number of genes we have and become large and complex. I think the turning point in all of evolution was the acquisition of mitochondria.

Dr. Biology: For the bacteria that are the same as they were four billion years ago, basically, I think you said they were stuck in a rut.

Nick: Yeah. The level of their biochemistry, how cells actually work, all the proteins that they have, the functions that they do, they're incredibly complex, far more complex than we are, but they remain tiny.

Although they can exploit all of these different environments, they never became large and complex as organisms. There are no bacterial people or bacterial plants or bacterial fungi. They just don't exist. They've stayed stuck the way they were four billion years ago. They didn't change.

Dr. Biology: On Ask a Biologist, none of my biologists or scientists gets out of here without answering three questions. Are you ready?

Nick: I'm ready.

Dr. Biology: When did you first know you wanted to be a scientist?

Nick: Probably when I was about 15 or 16. Before that, I don't really remember very well. I love science, but I loved all kinds of other things as well. I started reading books around 15 or 16, popular science books.

I didn't like them all necessarily, but I remember reading Richard Dawkins at that time, "The Selfish Gene." I really hated the book, but it really forced me to think completely differently about what I thought life was about.

That's a really important thing. I think it was the first lesson I had as a budding scientist was to challenge the way I thought about things, and try and find arguments, try and find other ways of seeing it. Now I could, but then I didn't see many arguments against it.

I read other books. I read James Watson's "The Double Helix," which is a classic book. Very inspiring because it was really all about the excitement of research and the possibility of Nobel Prizes and all these kinds of things that people dream about.

When you become a scientist, you stop dreaming about those things largely. Still, it's part of the excitement that drew you into science in the first place. He captures that really well.

Dr. Biology: You had quite a career as a scientist. You've also had an amazing career as a writer. What got you started writing?

Nick: It's a strange story. I entered a competition, a writing competition, when I was doing my PhD. I always wanted to be a writer, I think but I'd had it knocked out of me. When I finished my degree, I wrote to "New Scientist" and said, "Did you have any jobs?" They said, "No. You need to get some experience. Go off and work for some small journal somewhere and become an editor."

That held no appeal to me at all. I liked the idea of writing articles for New Scientist or "Nature" or somewhere. I turned my back on it and went on and did the PhD, but I was encouraged by my supervisor to enter this essay writing competition, which I did. I was a runner-up. I didn't win outright, but I was one of the runners-up.

When I finished the PhD, I had at the back of my mind that, well, maybe writing is still a possibility. I did a short post-doc job in the same lab, but this has to do with kidney transplants. I didn't feel like I was solving the problem.

I think science is about solving problems. If you don't know how to solve the problem, then it's time to move on to something which is more soluble, perhaps. I knew I had to stop doing what I was doing. I looked in the back of New Scientist, as it happened, where they have jobs advertised.

I was looking for a post-doc position that was doing something that drew on my skills but in a completely unrelated area or writing jobs. It turned out there were some writing jobs. I got one. I really liked the guy who interviewed me. I took the job.

I did that for several years. I learned to write really that way. When I say, "learned to write," I learned to lose myself because I think we probably all, probably especially me, have a tendency to over write, to try to be a poet, to try to use long words and construct beautiful sentences that are difficult to read.

This was writing plain and simple English for an international readership. In fact, a lot of the time, it was actually doing video animation to try to visualize the inside of a cell. You'd have to go step by step and say what's going on in very plain simple English. I learned to write simply that way.

Dr. Biology: I'm going to take it all away from you. You can't be a scientist. We know you're an author. I'm going to take away that, and just about every one of my scientists that are in university love teaching. I'm going to take the teaching away.

Nick: [laughs] All right. OK.

Dr. Biology: What would you be or what would you do if you could do anything or be anyone?

Nick: There are so many lives that you could imagine you might have led and probably you never could have done. I used to play...I do play the violin folk music on the fiddle much easier than the classical.

I grew up playing classical music. It was too hard for me, though I tried very hard at the time. I used to think it would be great to play the violin in a pit orchestra, playing Italian operas and travel around from opera house to opera house in Napoli and Rome and things like that.

That would have been a nice life, but probably I was never good enough on the fiddle. I'm just playing Irish music on the fiddle, but the trouble with that is you think of it as a life and immediately you think of "The Blind Harper," or Karen, who ended up dying in a ditch because nobody can make much money out of playing folk music unless you're superlatively good.

Other things, I don't know. I used to work on a forestry ranch. All kinds of life you could lead, I suppose.

Dr. Biology: Maybe a fiddle player?

Nick: Maybe I'd have been a fiddle player. I used to do a lot of mountaineering. That would have been another kind of a life, not a life to make a living but a hell of a life to lead, to travel the world and to climb the mountains. I don't know how you make a living out of that, but some people do.

Dr. Biology: Yeah. Give me a photographer as well along with that.

Nick: I think the adventure in science is as great as the adventure in any of these adventurous lives that you could choose. It's the adventurous life in itself. That might not come across if you would picture a scientist as someone in a white coat in a lab or something.

It seems very unadventurous, but actually, the intellectual adventure and the feeling that you're at the edge of what humanity knows and maybe you can pioneer that boundary a little bit, that's an adventurous life, too.

Dr. Biology: In fact, a lot of the biologists are adventurous because they're going places in the world that a lot of people can't get to.

Nick: I really wish I did the kind of science that would take me to some of those places. I've never managed to find an excuse to go to the bottom of the oceans, for example.

Dr. Biology: [laughs] You need to get to those events, right?

Nick: Yeah.

Dr. Biology: The last question I have is what advice would you have for a young budding scientist?

Nick: Follow what you're passionate about. Follow what you're really interested in because science is a very odd career. At least in England, it is. I don't know how it is in the United States, but this is the advice that I give to my own students when they come to me asking what they should do. Should they try and go into a field of science, which it looks that there's lots of funding there, for example, and there's lots of jobs there.

I encourage them not to do that but to do what they really enjoy doing most because in my experience, scientists just love science. They love the questions. They love the experiences. They really love kids who come with a genuine interest in what they're doing.

They want to help them. They want to encourage people to go into the field that they personally find is really interesting. If you follow what you really like yourself, the opportunities will somehow materialize.

It's amazing how they do, but they do materialize for the people who are really genuinely enthusiastic about what they're doing. Follow your heart. That's my advice.

Dr. Biology: On that note, I would very much like to thank you, Nick Lane, for visiting with me.

Nick: Been a great pleasure. Thank you very much.

Dr. Biology: You've been listening to Ask a Biologist. My guest has been biochemist and author Nick Lane.

If you'd like to learn a little bit more about the immune system and those nasty viruses, whether they are living or not living, you can either Google the words "viral attack." That should be a number one result, or just go to the Web address of askabiologist.asu.edu/viral-attack.

The Ask a Biologist podcast is produced on the campus of Arizona State University and is recorded in the Grassroots Studio, housed in the School of Life Sciences, which is an academic unit of the College of Liberal Arts and Sciences.

Remember, even though our program is not broadcast live, you can still send us your questions about biology using our companion website. The address is askabiologist.asu.edu, or you can just Google the words, "Ask a Biologist." I'm Dr. Biology.

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