Episode 41 – Ram Krishnamurthy: Astrobiology, origins of life and the search for extraterrestrials

Drew (00:07):

Thanks for dropping by listeners. This is Science Changing Life, and I'm Drew Duglan. Today, we consider how we got here, specifically the type of chemistry that allowed life to begin on earth billions of years ago, and taking us on that journey is Ram Krishnamurthy, who studies these prebiotic reactions and tries to determine what could have led to our very humble beginnings. So let's join Ram as he gives us a window into his own beginnings and how some major philosophical questions spurred his interest in chemistry.

Ram (00:37):

I was born in India, uh, port City called Chennai, and my interest in science was particularly kindled in chemistry. Somehow, you know, I will like gravitate towards chemistry for, I, I had a fascination with these molecules, you know, they would dance in my head, sometimes, come in my dreams and I used to even sleep with chemistry textbook beneath my pillow sometimes in the hope that it'll just seep into my brain. You know, that, that, that's how crazy I was.

Drew (01:04):

Did you have that burning question then of how life started and, and where it all came from?

Ram (01:10):

No, but in the Asian or the Hindu philosophy, you know, there was always this push to ask questions. You know, the question is what is real? You know, what is the absolute real? I was gravitating towards such philosophical question as well, why things the way they are? Why couldn't it be otherwise? Why should it be? For example, when we say, why is the sky blue? We can give reasons as to, you know, the wavelength, et cetera. So we are explaining how the sky is blue when we answered that questions. But it was not until I really came to the US that, you know, the origins of live question really bloomed in a scientific context. But it was already seated in my mind through watching Carl Sagan's Cosmos series. That was the time it was coming out and you know, it was broadcast on Sundays in, in India.

(01:57):

So we would all finish our lunch and sit in front of the TV and watch Carl Sagan traveled in this voyager ship towards different lands. And one episode that really caught my attention was the one where he talks about this Japanese islands where they, the crabs have the, almost the face drawn of the Japanese warriors. It, it looked exactly like those warriors. And the question was, how did this come about? And you know, how he was explaining through natural selection and things like that began to appeal to me very much. And so that is how I got interested in the kind of origins of how things are the way they are and not otherwise.

VOICEOVER: Drew (02:38):

To gain insights into these early origins, Ram's team studies, prebiotic chemistry, the kinds of reactions that could have first led to the emergence of life. And with some seminal work decades ago, it was shown that a few simple molecules have the potential to become the building blocks of biology that we see around us today.

Ram (02:57):

The earth is supposed to be close to 4.85 billion years old, roughly, give or take 4.5. And then the question is, when the earth was an inhospitable place at the very, very beginning, the question was what sort of chemistries could have survived, or what sort of processes could have gone on and survived? And then when the earth cold, there was enough water to settle on the earth. And then there's also a question about how much land mass was there from the very beginning, whether there was land mass or not. And there is the geochemical reality or the setting that needs to be right for certain chemistries to take place. But what people began to do when they wondered about this origins of life on earth, they really looked at first the type of chemistries that would go on. For example, in the late 1800s, there was a chemist by the name of Butlerov who studied formaldehyde.

(03:54):

He just took formaldehyde and put it in highly basic solution. And after some time it turned out to be kind of darkish brown, you know, or even black color. And he tasted it and it tasted very sweet. And what he found was he had produced sugars from formaldehyde. So it became known as the foremose reaction where people said, oh, a simple molecule like formaldehyde can give you building blocks like sugars. Then came the very famous Urey-Miller spark discharge experiment in 1953-54, where, you know, Stanley Miller showed that when he took simple gases like hydrogen, you know, methane nitrogen or ammonia and water, and then did a spark discharge experiment like an uh, lightning on early earth atmosphere, he produced a mixture of compounds. And when he analyzed, he found simple amino acids. And that was a paradigm changing thinking in people's mind that, oh, you can start with simple molecules that have nothing to do with life, but then you bake these building blocks that has everything to do with life. And that's how this prebiotic chemistry was born.

Drew (05:01):

And is that the same as astrobiology? Because I've seen your name associated with that term as well.

Ram (05:07):

So astrobiology is taking it and not limiting it to our earth, but then just taking it and expanding it throughout the universe. So the NASA astrobiology program has a very broad goal of trying to find out how life arose, how life evolve, and how life survives, not only in the context of our own single data point that we know in the universe called Earth, but how we can also use it to search for life clues of life, biosignatures of life, whether life could have existed on a planet or did exist on a planet and go extinct, like for example in Mars, you know, as the current explorations are going on. So it, it takes it and expands it to the universe, universe and you know, it really calls for your deep questions. Are we alone? You know, that's the, that's the question that they're trying to answer.

Drew (06:03):

And I'm glad you brought up NASA and I believe you are actively collaborating with them, aren't you?

Ram (06:08):

They have been one of my strongest supporters in this quest of, you know, origins of life. Of course, NASA is very much interested in that question. And they've also asked me to be part of a certain initiatives that they have taken. One of them is called the Research Coordination Network. It's called the RCN, and one of the RCNs is prebiotic chemistry and early earth environments. So the question for us is now we have, you know, since the 50 years of Stanley Miller's groundbreaking experiment, the question is, we have moved so far in terms of demonstrating so many different pathways to biological molecules.

But then the question becomes, how would these reactions that you discover today in the lab translate to an early environment scenario on earth? Where would you find these kind of chemicals that you would want? For example, I may do a type of chemistry that would require a certain concentration of a chemical under a certain temperature under which that reaction works.

(07:05):

The question is, is that feasible on early earth? So those kind of questions come up because now we have a fairly good idea of the type of chemistries that we can demonstrate in the lab, but then the question becomes, are these demonstratable chemistries realistic in an earlier scenario? And so we are working, you know, so that is the aim of this research coordination network to bring the researchers from different areas, one who might be a geochemist who has no interest in prebiotic chemistry, but is just studying the geology of a certain area which may provide a certain constraint on the type of chemistry that we can do in the lab.

Drew (07:41):

You're almost doing some kind of historical detective work then. Does the stuff you do in the lab, would it be realistic given the, the context of the planet back then?

Ram (07:51):

That's correct. So it is one part historical, and that is the problem with this origins of life field, when we try to make it historical, there will always be the questions, how do you know? So when we do some reactions, people will come and ask us, do you know this is the way that it exactly happened on early earth? And that is where the problem lies. Early earth has actually erased most of it history, not all of it. But the problem is when you want to really pinpoint the type of chemistry that might have happened, that chemical fossil, if you will, has been erased. So some of the prebiotic chemists like me for example, sometimes try to be away from the historical questions and try to discover chemistry. And once we discover some interesting chemistry, then we try to walk our way backwards to see whether it'll fit or not. And if it doesn't fit, so be it.

VOICEOVER: Drew (08:45):

There are several prevailing and competing theories on how life may have begun on early earth. One is the protein world theory where the amino acid building blocks are produced first, which can then come together to help make the other classes of molecules. The second is the RNA world theory suggesting that single stranded genetic information began first to emerge, which then laid the blueprint for everything else. Then we have the proponents of the metabolism world theory, who suggest that none of these other building blocks could have emerged without initial energetic reactions and their products. And finally we have the lipid world theory whose supporters suggest that none of these other reactions could take place without an enclosed protective oil-based vessel. So with all these competing theories flying around, what is Ram's opinion?

Ram (09:34):

So there is a protein world, RNA world, lipid world, and a metabolism world, and all of them have connotations with biology. And in my view, all of these were valid in terms of thinking about it. But in my opinion, they are all taking biology in a historical sense backwards to a place where there was no biology. So my doubt with these approaches is that are we trying to fit too much of biology on an era where there was no biology possible or no biology at all, and trying to find only the molecules that would fit, extend biology and ignore the rest of the molecules that are not in biology today? So our lab takes an approach, which I would call not guided totally by biology. So what we try to do is look at molecules that might exist in prebiotic chemistry along with the molecules that are formed, which would be of interest biology, but then use them as a mixture to find out if there's a pathway that naturally emerges without me wanting to know what the outcome is. So the way I ask or frame this question to people who say, what is wrong in using biology? I say, let's say you land on an exoplanet and you see the chemicals that are available to you from the chemicals that are available, can you immediately predict what should be the biological construct that would come out of those chemicals? You don't.

Drew (11:09):

I see. So would I be right in thinking then that you are kind of taking that chemistry there on the ground floor and seeing where it goes as opposed to looking at life and re trying to retro engineer what happened?

Ram (11:20):

Yeah, so one of the examples that I try to give to understand is let's us say I am, you know, coming from a village in India, you know, where there are only mud houses with the roofs that are made out of leaves. And then I land in New York, and I'm just using the twin towers as an example. So I land in New York and I see these two huge twin towers and my jaw drops. I said, how could they construct such a thing? My thinking would be coming from my experience of houses that were built in my village, I would say, oh, they built brick by brick, layer by layer. They would've then done this. Then they, people would've stood on the shoulders of people who have done that and things like that, or they would've taken ladders. But then somebody comes and says, no, no, no, there are these huge cranes you don't understand.

(12:06):

These are these huge cranes that come and build things. But then I would say, but I don't say evidence of cranes there, you know, where are those cranes? And then they put a movie for me where these cranes come and they go and they, all the arrangements are there. And then so you have a building, but which does not bear any resemblance or have evidence of the process that built it in the first place, right? So we are looking at these end products in biology, which uses, uh, of sophisticated enzymes and sophisticated metabolic pathways, which would not happen if the enzymes were not there in the first place. And then we are trying to take that sophistication and plunge it to 4 billion years ago into a primitive place where just sophistication does not exist. So that is my take on it. I'm not saying that is the correct take. That is how I think about it and trying to free myself from the way that I need to think about biology, but trying to see if these kind of biological behaviors can naturally emerge from a mixture under a given certain conditions.

Drew (13:07):

Great analogy. Yeah. So I want to go back to something you mentioned, which is very interesting that you said. Uh, was it the, a lot of these amino acids and some of the other building blocks are actually found in meteorites. So is that indication of life or is that just a presence of building blocks?

Ram (13:23):

<laugh>? So for me, that's a very good question because that's how it starts, right? You know, when you see the amino acids that are present in your body, you know, reflected in a meteorite. But the thing is, for me, what it just says is the chemistry is universal. The chemistry is universal, but life is a different question for me. That's at, at a much higher level in terms of using that as a proxy for life. And that is

one of the big questions that NASA is interested in is how do we search for life when we know such abiotic chemistry that happens on the meteorite, also gives us biological building blocks. How do we not confuse it? So there are ways you can overcome commit, but there's always this s nagging question of what you find is actually a sign of life or could be interpreted as a sign of life versus an abiotic chemistry that could give the same result.

Drew (14:13):

So in your opinion, what is the threshold signature that would constitute actually life?

Ram (14:22):

That's a very difficult question, because that goes to what definition of life is. Sure. You know, if we define life like what we see today, then I would need somebody waving on the meteorite to me. You know, that's impossible. Of course. No, no, it's, it's a serious question because if you think about before the invention of the microscope, all the life that we knew was what this ice could see, but with the invention of the microscope, it opened up a whole world of microbes where you didn't have to change the definition of life, but you had to change the definition in terms of the size that would be life.

Drew (14:55):

What do you think this would mean if we sort of understand how life started on earth, you know, in terms of the implications for the wider science community and society, and I don't know personally as well, what do you think?

Ram (15:08):

So one of the things that immediately jumps out to people is, you know, they are scared If we can begin to reconstruct life as the way you know, or understand origins of life and reconstruct, do we begin to construct artificial life? Uh, why, where does it take it? What are the ethics? You know, the same thing that happened with CRISPR in terms of can you create gene editing babies and things like that. Those kind of things come about. So the society as a whole will need to have a good discussion about what are the ethics and moral implications when such an scientific milestone is reached. The question is whether there is going to be, uh, benefit or when there is going to be a downside to it, and how do we manage both of them? So we have to be extremely careful about it.

(15:55):

Now, to your question about life in the lab, there have been very enthusiastic claims made in the past by very good friends of mine. They have never come to fruition. Some people said in 10 years, 20 years, 30 years, we are way past. It just shows that we still have to understand quite a lot about this process. And my submission would be that if we are humble enough to learn from what the science is teaching us, it'll show us a way and it might show us also the limits of whether we will be able to achieve it or not.

Drew (16:26):

Yeah, it's a big, uh, existential question really. So going back to NASA, what do you think of this search vector to trust your life? Do you think we have made any progress? Do you think it exists? What's your take?

Ram (16:40):

So there are very serious discussions, you know, what are the implications? You know, the question is always framed in a very big appealing manner to the general society, the layperson, are we alone? So that is a gripping question, you know, right from, you know, the famous HG Wells novel about martians attacking us to lot of invoking, lot of other things. One, one of the things that really fascinates me is, um, Mr. Spock and Captain Kirk, you know, the, I always go back to that and the type of life forms that Spock has to deal with, you know, which is in the shape of a blob based on silicon and those kind of things. So it's a very hard answer to say yes or no definitively. So you always end up in this grayish, maybe based on the no equation type of approach, where you say the probability of having, you know, so many worlds and so many universes and so many exoplanets, what is the chance that you will not find life on at least one of them right now?

(17:40):

That is a very, very optimistic way of thinking about it. But it is also in a way philosophical. There is this very famous eastern philosophical mind game that people play. If a tree falls in the forest and you're not there to hear it, does it make a sound? So the question is, even if there is life out there on a planet exoplanet that we can't possibly in our lifetime or even in the earth's lifetime, reach that and get back the information that there is, life is there no life on the planet. So I, it's a very, it's a very difficult, it's a struggle. It's a struggle in terms of trying to answer it, answering it definitively. It's something like the UFOs, if you will, right? You know, we have seen these images and we have, you know, all these theories about, you know, what it should be, what it could have been, who is hiding, what, what are they hiding where, and things like that. But we are not able to come to a definitive conclusion. So let alone about, um, an, a life that might exist on an exoplanet far, far away.

Drew (18:40):

Well, when, you know, studying prebiotic chemistry in the lab, I'm, I'm curious what some of your other hobbies and, and passions are outside of research?

Ram (18:48):

Um, one is philosophy. I would say probably philosophy is the, you know, one that keeps me grounded when I do research in this field. So I like to compare different philosophical approaches, the thoughts of each and every, I won't say religion, but more of a philosophy. Then I do a lot of, uh, volunteer work within our own community to try and teach the next generation of the Indian community here about our own culture, our own philosophy and balance, the demands of growing in a completely different culture versus preserving our culture to assimilate both in a, in a positive sense, you know, make, not trying to make judgments one way or the other, but trying to see the differences, but then also try to take the strength from those differences to make a pathway that would be conducive for my own growth. And apart from that, there is, you know, always the meditation that is there, uh, that comes along with my practice from a very young age, and the traditional spiritual practices that are coming through our lineage, our families, and things like that, that are handed from generation to generation. We try to keep that alive.

Drew (19:58):

That's great. Yeah. Oh, meditation is, is fantastic. It must be very good to sort of clear the mind too with all the, the research.

Ram (20:07):

And you know what the funny thing is? What I find is when I find something very scientifically and intellectually satisfying in terms of finding a concept or a new reaction, that actually reinforces the type of feeling I get from meditation. So I don't see them as two different things or, you know, two parallel things. I actually see them as two intertwined things.

Drew (20:29):

Yeah, it's like you're very present in the moment and, uh, yeah, I were, alright, well maybe I'll just, uh, finish up with my final roundup question, which I like to give all my guests, which is, um, you know, if you could give that one piece of advice or your wisdom to, uh, anyone, whether it's, uh, with work or careers or life, health, whatever it could be, what do you think it would be and why?

Ram (20:51):

So when I got into this field, I started out as an organic chemist, trained purely as an organic chemist, but then found my passion in this field where I used that organic chemistry to try and answer these kind of, um, questions of what sort of chemistry would give rise to a, an entity that would exhibit life like properties. So based on what I have seen or experienced through that journey, my one piece of advice would be to the people to find out what you do best and what is your, you know, strength. It might not be immediate, your immediate passion or it might be not even your long-term passion, but find something that you are really good at where you excel at it in, in such a way that it immediately gives you a foothold to then spring to what you really would want to do as a passion, but that might be a little more risky. So I liken it to a mountain climber. So people who climb mountains, they know that their hand will be searching where they would need to put the grip, but their leg would never let go until they are sure about the hole that they have on the top. So it's something very similar to that. So have a very good foothold. Don't let go until you get the next good grip. Otherwise you will fall.

Drew (22:15):

Some lovely wisdom there from Ram. And it was great to see modern science combined with ancient philosophy in these attempts to answer such fundamental questions. In the show notes, you'll find more on Ram's origins of life work, as well as other links to fresh new features and videos from the Scripps Research Magazine. It was a pleasure having you with us, and please remember to follow or subscribe and hit that five star rating if possible. We'll be back soon with more scientific leaders answering tough questions. So until then, stay curious and take care.