SCIENCE OF THE NOOSPHERE

Bruce Damer and Matthew Segall

With

David Sloan Wilson

David Sloan Wilson: Okay, well, hello, friends. I'm so happy to have this conversation with you about major evolutionary transitions pretty much from the origin of life to the present, to the internet age and beyond. This is going to be great, but first, I'd like to have you introduce yourself as people, and how you wandered into this peculiar line of work. Bruce, would you like to go first?

Bruce Damer: Yeah. I was a very nerdy little kid in Canada into board games, eventually into writing code in the '70s, and I came upon this question of life's origins as perhaps the most interesting kids' nerdy idea. And so, I pursued it for the last 35-40 years, and it was basically the question of: how did a jumble of things like Tinkertoy or Mechano or things you play with when you're little. How did those self-assemble on their own in a natural system and start organizing and start making copies? It was completely fascinating to me.

And so, I was in computers for a long time. I did a lot of work for NASA in spacecraft design and big systems for them and then met Professor David Deamer at UC Santa Cruz, who's my colleague, 10 years ago. Together, we co-joined our efforts in membrane biophysics, versus computer systems and complexity, to come up with our current hypothesis.

DSW: And, Bruce, at what point did you encounter Teilhard and the concept of the Noosphere?

BD: Actually, back in the '90s, I think about '94-'95 when the world wide web was getting going, Teilhard came back of age. We were at a conference in Italy in Florence, and there was a big conversation amongst us about Teilhard and the Noosphere. "Is this what we're seeing emerging?" It was about 1996. Is this what was emerging? We were part of the Marshall McLuhan program at the University of Toronto, and it all seemed to be linked together, McLuhan's ideas and Teilhard's ideas. Very, very exciting and it never left me, that conception.

DSW: Wow, that's great. So, Matt, how 'bout you?

Matthew Segall: Yeah, thanks, David. So, I, since high school, can remember being curious about big questions. Early on, I centered on human consciousness as the site that I wanted to inquire into. And so, I majored in cognitive science as an undergraduate. But unfortunately, consciousness wasn't much discussed. Mostly, it was neurobiology and computer science and a bit of linguistics and behavioral psychology and whatnot, so a lot of my reading on consciousness as such, I did out of class. But, I found this graduate program where Brian Swimme is a faculty member, and others, where consciousness was put in a much broader cosmological context. And so, I ended up getting my PhD in that program and now teach for it. It's the Philosophy, Cosmology and Consciousness program. You can see in the title, quite interdisciplinary if not transdisciplinary. And so a lot of my research now is looking at how human consciousness fits into this larger evolutionary process, which is biological but also, the earth itself came into existence 5 billion years ago, and there was almost 10 billion years of cosmic evolution prior to that. So, I'm very interested in this whole context.

DSW: Yeah, and so when did you encounter Teilhard? And also, Whitehead is an important person for you. Maybe you could actually talk about those two individuals together.

MS: Sure, yeah. I think, Teilhard, I probably came across my first semester in graduate school, actually. It was reading The Human Phenomenon. Whitehead, similarly, I started studying him formally in graduate school, but had heard of him in some lectures by a well-known psychedelic philosopher who Bruce knew personally, Terence McKenna. McKenna's ideas can be pretty out there, but he did draw on Whitehead in order to understand the nature of time. He drew on Whitehead in interesting ways that piqued my interest, so, in graduate school, I got around to studying his process philosophy more deeply and continued to research and publish a lot on the relevance of Whitehead to contemporary science, physics and cosmology as well as the life sciences.

He and Teilhard of course share a basic sense of the universe as a process of evolution, an evolutionary process. So, Teilhard's term cosmogenesis is one that I use frequently to describe Whitehead's understanding of this process. They helped us understand the relationship between science and religion in a way that is still unfortunately rather uncommon in our contemporary culture. They see science and religion as potentially mutually informative of one another with religion adapting to the discoveries of science and science accommodating the spiritual insights of religion. So, I draw on both of them in a lot of my thinking, trying to imagine a more integrative mutually enhancing relationship between these two important human projects, science and religion.

DSW: Yes , and the idea that religion can be about a process of bringing into being, basically, and really not invoking supernatural agency at all. So, anyone who shies away from religion because of its invocation of supernatural agency actually should take a strong interest in process theology because process theology doesn't invoke supernatural agency, and neither did Teilhard, for the most part. Hardly anybody knows that, and that's one of the things that we'll be discussing. Well, Teilhard and The Human Phenomenon or The Phenomenon of Man told a story that began with the earth before life, and then the origin of life and the biosphere, and then the origin of humans and the Noosphere and the expansion of the Noosphere all the way up to a global consciousness, which he called the omega point.

We're going to go through that ourselves in three acts, I think, which makes it so interesting. One is the origin of life, which is, Bruce, your specialty, and then the origin of humans, which I might take the lead in describing what I think the best of our current scientific knowledge is, and then the current day, the internet age and the global consciousness that, in my opinion, does not yet exist, but needs to be brought into being in true process fashion. That's a lot to get through, so let's just begin. Bruce, tell us about the origin of life.

BD: In a nutshell.

DSW: In a nutshell. And your amazing hot springs hypothesis, it's an amazing story. I wish I could spend hours and hours on it, but give us your elevator speech for the origin of life in the hot spring hypothesis.

BD: So, what I will give you is what I give someone in an elevator, a random person in Omaha, Nebraska, riding up to the 10th floor. That's the time we've got. I basically ask them, "When you take a bath, a bubble bath, what happens as the bath drains?" They'll say, "Well, there's bubbles, and then they create a ring around the side of the bathtub." I say, "If you take a lot of baths, is it easy or hard to clean that ring?" They say, "It becomes harder and harder to scrub the bathtub ring off my bathtub." I said, "Well, it's because, if you looked at that ring, it would be thousands of layers of fatty things, of what we call lipid would have formed," and this is the very place that we think life can get started in that ring around a natural bathtub called a hot spring that's filling and drying, filling and drying, filling and drying.

And, instead of bubble bath being sprinkled in, it's getting dust and meteorite fragments from the atmosphere as the earth is forming. There's this great big disc of dust in the solar system, and we're vacuuming it up as we go along 4 billion years ago. And then, all this stuff is in, basically, your primordial soup of this bathtub in the hot spring, and it's just a perfect place for something called polymers to get together. So, in those dust particles are the building blocks of what we call now proteins that help run

our bodies, and some are the building blocks of nucleic acids, which is RNA and DNA. They're floating around in this hot spring. They're getting all kinds of energy, ultraviolet energy. They're getting together in these little fatty compartments that are forming like bathtub bubbles.

Those fatty compartments dry down into that ring, and, as they dry down, it pulls together all the little building blocks and makes all those components of what we think led to life, which would be these little peptide amino acids and nucleic acids that form something like RNA and DNA. They're all contained in those layers that then bud off when the pool refills and you have more bubbles. And then, there's this process of mixing and stressing the bubbles. Do they pop or do they not? Then, the growth of these things called polymers, and the polymers start wiggling together and talking amongst each other and they talk to the membranes that they're inside of, the compartments they're inside of.

This process is the beginnings of what we call combinatorial selection, before genes, before quasi-genes, before the simplest things. We now have actually demonstrated this in the laboratory and in hot spring environments, specifically in Rotorua in New Zealand. We've actually run this experiment in those environments in the natural analog that would have been available on the early earth 4 billion years ago, these big volcanic archipelagos. And so, not looking any more at an origin of life in the deep oceans because everything is so diluted. It's a big dilute bathtub where no rings can form, or at hydrothermal vents at the bottom of the oceans. We're now back in hot springs where Charles Darwin actually, 150 years ago this year, in 1871, wrote a letter to TJ Hooker saying, "I think life could begin in a warm little pond somewhere." So, we're actually returning to Darwin's intuition, taking our science back on land, back to hot little cycling puddles, we call them, or pools.

DSW: Right, so it's not required for Darwin to have anticipated absolutely everything, but it is amazing that he did have that warm little pool passage. What we're trying to explain here, of course, in the transition from non-life to life is an evolutionary process. A Darwinian process requires units, something that is being selected. Those units need to vary. And then, of course, those differences need to make a difference in terms of their survival and reproduction. And then they, in some sense, have to replicate. So, the essence of a Darwinian process is variation, selection, replication, and that's what we're seeking to explain with any theory of the origin of life and what you described for what might take place in hot springs.

In some ways, it sounds so fanciful. But, reading about it, it seems that, actually, it makes a whole lot of sense. I'd like to know how much consensus there is about it among the community of researchers on the origin of life. Is this something that's already been agreed upon? If not, what are some of the other viable theories? You've already discounted the deep sea vent hypothesis. How much consensus is there on this hot springs hypothesis?

BD: David, we could be well within what would be called a paradigm shift by Thomas Kuhn in his great book from the 1960s, The Structure of Scientific Revolutions because we've had basically two dominant paradigms in the past: a primordial soup and sparking of the atmosphere and the primordial mixture that came from some of our predecessors. And then, we had the discovery of hydrothermal vents in the ocean, which had energy gradients and had sources of redox energy and everything you think that the modern cell would need because a modern cell runs, of course, using energy gradients.

But, 30 years of experiment has never been able to produce more than very trace amounts of organic compounds synthesized in these deep sea vents. So, the field was kind of adrift and many researchers, mostly chemists, were frustrated by all this. When we proposed the hypothesis about five or six years ago, there were a number of groups willing to go there because they could do the experiments we were doing and reproduce them. So, four or five groups replicated our experiments.

And then finally, a year-and-a-half ago, Nature ran a major story about this, which sort of broke it open into a controversy and we realized that the paradigm shift was underway. Many of our colleagues weighed in in that very article, so we think that the field has now shifted to pools on land. Other proposals have been lake environments or spring environments where there are large bodies of water. Pretty much everyone agrees it has to be in elevated temperatures and a way to concentrate things. And so, things seem to be centering around hot springs or very concentrated mineral environments. That's where we are. We're in mid shift at this point.

But basically, there's a lot of field studies now, where people are going out and replicating these experiments, and no one predicted that would work. They thought it would be too complex, or the geochemistry, the dissolved ions would get in the way. It surprised even us when we came back with the first samples from Rotorua that we had four times the yield from the hot spring environment than we would have in laboratory water. We worked out that it was ionic components, so it's been a surprise all the way along. And then, on the geology side of this, we also have colleagues that are researching the very early earth, notably University of New South Wales. Geologist Martin Van Kranendonk and his team go up into Northwest Australia into the Pilbara area, and they, for the last 30 years, 40 years, really, have been basically discovering these stromatolites, these wavy textures in the rock. This a Paleoarchean environment 3.48 billion years old. At the same time as Dave and I were literally drafting our initial hypothesis paper in 2014, they discovered, Martin and his graduate student Tara Djokic, they discovered hot springs, basically geyserite, a type of mineral in a band of rock that showed preserved evidence of microbial communities.

That led to a Scientific American cover story which brought it all together so that the early earth discovery of hot springs on land replete with rich microbial community plus this proposal for its origin in the hot spring came together in perfect synchrony. We went there and we saw those outcrops and we started to work with that team, which led us to work on the Mars landing site selection for the search for life on Mars. So, it's been one of these remarkable decades of synchronous discovery all over our field from computation to geochemistry to the early earth rock record coming together all at once in this single model. So, it's quite remarkable to have lived through this.

DSW: I'll bet. Matt, what do you think of all this?

MS: Well, as a process philosopher, the first time I heard Bruce describe the hot spring hypothesis as a result of this cycling of wet and gel-like and then dry phases, I immediately felt the resonance with Whitehead's understanding of creativity and what he calls concrescence, which is his fancy word for how novelty emerges in nature. So, I saw what Bruce was describing as a special example coming out of research into the origins of life of Whitehead's general metaphysical understanding. And so, Bruce and I have talked a lot about how to connect his abiogenesis research with Whiteheadian philosophy, and I think the term creativity is the way to go here, that somehow physics and chemistry, in a totally non-supernatural way are creative.

Typically, we would want to say creativity is something that belongs to human beings, human artists, maybe scientists as they make discoveries, but Whitehead wanted to say, "No, creativity is a feature of the universe as such, and, for the origin of life not to be in any way a miracle implies that there's some kind of continuity here with chemistry and physics and thermodynamics, and that we can understand life as a natural expression of these physical and chemical processes." And yet, there's also something new emerging. So, how do we both preserve the continuity as well as the uniqueness of this new process that we call life?

So, as a Whiteheadian philosopher, I think Bruce's research, his colleagues' research is really helping to narrow the gap between physics and chemistry and life in a way that ultimately, I think, will also help us narrow the gap between life and consciousness, or mind, if you'd like, because there's a similar creative principle at work, totally naturalistic, at work in both of these transitions.

DSW: Yeah, and so, evolution, almost by definition, is a creative process because it's bring new things into being, things that did not exist in the past. The periodic table will forever be the periodic table, but, with organisms, the future need not be constrained by the past.

MS: Can I comment? Can I comment on that, David? The periodic table in particular. Part of the point I would like to make here is that the physical elements of the periodic table ... Teilhard, I think, points this out, I forget exactly where, that they emerge historically, not all at once. You have hydrogen and helium first. And then, those atomic elements form stars, which go supernova and produce the heavier elements. And so, there's a historical process, a creative process, as it were, even at the elemental level.

DSW: Cosmologically, yes, right, absolutely true. But, in the present day, the elements remain the same as opposed to a population which is changing over time, being shaped by selective pressures, basically. So, there is something generative, changing about an evolutionary process, which is not true for the nonliving physical world. I think that's why life is a demarkation point. But, you're quite right that, cosmologically, then, the elements themselves came into being through a historical process. Is that accurate?

MS: Yeah, and they've become ergodic, I think, would be the proper way to understand it. They've fallen into these thermodynamic sinks and they can't evolve further. But originally, it was a kind of historical process of unfolding.

DSW: Yeah, yeah, absolutely. I want to drill down and think about the interplay between cooperation and competition in this hot springs scenario. The units are, and this is what I learned from you, Bruce, and it was a new insight for me. I have to admit that I thought the first units of selection was some kind of protocell, but you actually, right away, begin with two levels of selection, which, of course, fascinates me. One is the protocell. And then, there's this kind of matrix of protocells. You have a word for it. I was going to check the pronunciation before this interview so I wouldn't embarrass myself, but now ... progenote, how do you actually pronounce it?

BD: That's correct, yeah.

DSW: And so, it's like life began not only as single protocells, but as primitive multicellular organisms of a sort. Could you clarify that aspect of it?

BD: Yeah, back to the elevator speech on how to bring this concept home is: when you have these little bubbles, what we're calling them vesicles or protocells if they contain some polymers. They're released into the bubble bath, into the solution when the hot spring fills up. They're floating around and the compartments are very friable. They're leaky, so some of them blow apart. Some of them lose their contents. The ones that have the membranes attached to the polymers that are within them tend to be more stable structurally, so that's our first selector we call the s-polymers, for structural property. It doesn't matter what the sequence of information in the polymer is. It will structurally stabilize that.

So, what we find is, as we do these one-hour cycles of 35 minutes of dry-down and 25 minutes of a heating bake in the laboratory dishes, or even in the hot spring environment, we find that the clump of these vesicles or protocells grows in size. Literally, the aggregate grows. It came as a sudden inspiration in the Australian desert back about five years ago when I was there with Dave Deamer. I looked outside. We were traveling by bus from basically the Perth area all the way up the West Coast of Australia. I looked outside and a typhoon had just come through, and the desert soils were moist. There was all this growth that would only last a short period of time because it gets very hot there.

I said to Dave, "Dave, in between the dry phase where everything is film like a bathtub ring and the wet phase where everything is in aqueous solution, the bubbles, there's a moist phase, and that moist phase is what is represented outside our window in this bus trip. It's where we have maximum metabolic

output. So, could it be that this interphase, this gel is a unit, is a unit that's important in the cycling system on the way to life, on the way to those first polymeric functions booting up in the network?"

I presented this in a conference in Houston, and in the audience was George Fox. George Fox was the graduate student of Carl Woese. In 1977, they wrote a paper about the third branch of evolution, the archaea, the discovery of the archaea. There's a little paragraph there that said, "Well, on the origin of life, we think that there had to be a unit, and we're calling it the progenote, before gene, that was an amorphous mass that was all horizontal sharing of genetic material, protogenetic, quasigenetic material. It was amorphous and it was kind of loose, and that that was the unit that could carry you from pure physical self-assembly, which is what we see in our bathtub soap, all the way to self-maintaining microbial communities.

And so, George said, "You have come as close as anyone to describing, and perhaps experimentally, being able to make the progenote that Carl and I came up with all those years ago. So then, we really took this apart. We took this early thinking apart and realized not only would protocells aggregate there, but the very structure of what they're in is a kind of prototypical niche construction. I later met John Odling-Smee of Oxford who had written a book called Niche Construction Theory, and we have worked for the last three or four years on this.

There's a new paper coming out from Jack Szostak's group at Harvard. Actually, it's in pre-print right now, and they're doing experiments with colonies or aggregates of protocells and seeing how they're more stable. pH becomes more uniform. They're more protected from shear forces in the water, and chemical circuitry can boot up within a networked effect of the protocell lumens where you have ... Basically, if you have a metabolic cycle, a catalytic cycle starting here, products will defuse to another lumen over here, so you get the beginnings of network effects of circuitry in that gel phase.

There's one last little point. If you're sitting by a hot spring and we're back in 4 billion years ago, and you're watching the pool dry down, it could be a single droplet of water actually drying down. You would see the sheen. When I look at the vials, I can see the formation of these gels in the bottom of the vial. I can see it visually. I can see layers and compartments. As the pool is drying down, the solute concentration is climbing, and solutes will be pushed into the gel. It's almost akin to a feeding stage where, if you're going to get metabolic cycle start in partial aqueous immersion with high concentration, it's going to happen collectively for that progenote, for that aggregate mass.

And, the last point to make is that aggregate mass, as it's made out of individuals that are quasi-individual that have to survive the robustness test of aqueous immersion, but then they come back into association, that aggregate mass is a robust distribution, so that means it could flow down a channel to another pool, or, as a dried unit, dried on a film on the surface in the bathtub where it can be blown by wind almost akin to seeds and spores. So now, we have a model that addresses some of the key questions. The temperable friability of hot spring environments means that, if you are in what we call an urable zone. It's a new term we're introducing to our community, urability as opposed to habitability. Urability is the ability for a planet or a local environment to originate life rather than habitability where life, if introduced, could survive there.

This urable zone is very narrow in these pools, so if you get a loss of organic feeding process, change in cycling, change in anything, suddenly, those chemical circuits won't work. So, if you distribute, the apple not falling close to the tree, if you distribute these progenote masses across a landscape, across many pools and then there's transmission back and forth as material is distributed, you solve a major complexity problem against these terrible degrading forces in those environments. So, we proposed the ... in a sense, that's Carl Woese' idea, but now mapped onto an actual proposed chemistry into a complexity, a fitness landscape, effectively.

DSW: And it's very reminiscent of biofilm for modern microbes, of course. So often, microbes survive only in biofilms within a matrix of their own making. And so, the idea that something like a biofilm was needed at the origin of life as opposed to a naked protocell, same goes for a naked bacteria, basically. Yeah, there's naked bacteria, but, so often, they exist in biofilms. That's amazing. And so, you've also connected this to the extended evolutionary synthesis, niche construction. These are ideas that are now avant-garde within the field of evolutionary biology.

And, part of the extended evolutionary synthesis, the part that I'm most involved in is the whole cooperation/cheater problem and levels of selection. I was a little surprised that, in your account, at least what I've read, Bruce, you don't talk about the cheater problem much and you don't use the word cheater much. But, the way that I would frame it is that evolution is always a competitive process because it's a process of change, and so some forms are replacing other forms. That's competition in the broad sense. And, Darwin had quite a bit to say. Darwin thought hard about the concept of competition and the idea that it was struggle for existence bothered him.

He said that, for him, competition was, he used it in a large and metaphorical sense. A drought-resistant plant outcompetes a drought-susceptible plant in the desert even though they don't interact at all, and that if he were going to use another word other than competition, he would have chosen equilibrium, which is really something to think about. But, what we talk about with any evolutionary process is a juxtaposition, a kind of a dance between cooperation and competition at various scales.

And so, first of all, the smallest scale would be what takes place within a protocell. That needs to be a cooperative process if the protocell is going to have any kind of integrity. If anything happens that's disruptive within a protocell, then that's the protocell that's going to fall apart, not the one that's going to survive. But nevertheless, that does happen and there's cheating molecules, you might say, that sequester the process and increase in a way that doesn't contribute to the common good. So, the concept of cheating can take place within protocells.

And then, this whole mass is a coordinated unit, so cooperation is taking place within the mass. That's also true for biofilms, and yet, that could also be competitive. So, there has to be some inter-mass competition in order for the better masses to replace ... the more cooperative masses to replace the less cooperative masses, but there could also be disruptive processes that take place within a mass. And then, let me quickly point out the work of Paul Rainey on real biofilms. We'll be talking with him in another conversation, but he does experiments, as you might know, now I'll tell the audience, in which, basically, microbes grow in an unstirred liquid medium. They deplete the oxygen, and, the next thing that happens is that they evolve mats that are held together by some polysaccharide or something that holds them up on the surface.

Well, it's expensive to do that, so the first mutants that do that, they form these mats, and now they have access to oxygen, so they spread. But then, additional mutations turn off the ability to form the matrix, and that's an energetic saving for themselves, so they spread within the mat and then the mat falls apart and then the whole thing goes down to the bottom. And then, that process occurs again and again and again. There's cheating for you and all of its characteristics. So, cooperation, competition, cheating at different scales, all that's going on in your scenario. But, I just wondered if you could say more about that. And then, we're going to transition to human origins where that's going to come in big-time. Anyhow, a little more about cheating, cooperation, competition and scales for your hot spring hypothesis ... Matt, I don't mean to leave you out of this conversation, so you definitely need to be taking your turn, here.

BD: Yeah, what I'd like to introduce for this group and the audience is a concept that has occurred to us in the last three or four months, which really shifts us out of this cellular thinking because, in truth, protocells are not cells. Protocells have no identity. They're temporary compartments for something that actually is more important, which is clusters of polymers in interaction. So, if you think in terms of cell-

to-cell interaction, a specialization at the origin of life, you're thinking the wrong terms. We started to look at, given that the polymers would attach to the membranes ... and, if you look at these membranes under a microscope, they're in constant motion. If you attach polymers to them, the polymers are moving around like cars on a freeway system, and this is still true of cells today.

We realized that, in fact, the whole action is probably happening membrane attached with vastly large populations of polymers moving around encountering each other in collision events. This calls upon some of Whitehead's ideas. This is the unit we have to look at for selection in evolution. We can't look at the unit of a vesicle with something floating in it because it's not crowded enough. It's not concentrated enough in there for much to happen. So, our colleagues at University of Washington have done a number of tests where they've attached peptides to membranes, and they predict that peptidyl to peptidyl collisions and interactions oligonucleotides, that this is actually where things would start.

So, we're rebooting our entire thinking into, this is the population we're selecting from and for. The membranes are the carrier. They're the matrix. They're the unit. They're the medium. But, all the action is going to be in these collisional events, in these probabilistic events which concentrate everything into a 2D medium from a 3D floating around volume. So, any things that happen as far as cheating or opportunism or even protovirus has to happen on these sheets and moving around on this type of a highway system, things coming into concentration. You'll find, in a way, it's like going back to Conway's Game of Life on that two-dimensional matrix. Next neighbors matter, but there's large travel.

You could actually model this fairly well in computer simulation, and that, I think, is the next frontier. So, it's a real reboot of the brain to think of the progenote in this term. We're also calling this overall matrix a progenitor, that which gives rise to biological functions and things with identity because it takes, through this progenian epoch that we're proposing, we're breaking up into early mid and late progenian. It's not a geological epoch. It's the epoch of life's boot-up phase. And, only in the late progeniean would you find cellular identity starting and cellular division. What you have to do, and I'll leave it at this.

You have to do thought experiments through this great dark chasm because the complexity of this transition is so immense and the numbers are so large that all you can do is take waypoints. What we're doing is we're taking the waypoint in the late progenian of the first viable protocellular compartment divisions, the first fission events, and asking the question as we work backwards, "What led to fission as a selected trait?" One of the proposals has been getting rid of the trash, budding off exosomes to remove inactive material, which is a simple process versus active pores, so, saying to ourselves, "In the late progenian transition to cellular division or actual cellular emergence within the community, not in a free-floating solution, is budding and division."

But, it has to join together with the replication of the quasi-genes and a lot of other material that are attached to the membrane as the membrane pulls apart. This is also the work at Szostak's lab in Harvard, that if everything's attached to the membrane as these vesicles start to elongate and wobble themselves apart, you will get daughter protocells, the way toward vertical descent, the ownership of genes, the ownership of nutrients because you're keeping the compartments.

DSW: We begin with fuzzy boundaries, is what you're saying, I believe. But then, variation takes the form of patches, I think, with fuzzy boundaries. Matt, I'd love to spend more time on this, but we need to transition to humans. Matt, do you want to make a comment on any of this? And then, we'll proceed to the origin of our own species.

MS:Sure, well, the problem of the one and the many is right at the origin of metaphysics, and I think, in the biological domain, it really comes to a head as well for all the reasons you two have been discussing. What is a biological individual and what counts as a unit of selection? Obviously, there are many different levels of selection, and, depending on what level you choose, you see competition or cooperation. I think one of the things that process philosophy can bring into this discussion is,

Whitehead wanted us to focus more on relations than on things. It's another way of saying focus more on processes than on things.

And so, what Bruce is pointing to in the origins of life is that the salient feature of these progenote or protocellular communities is the relations that are established between them. And so, rather than looking for the individual agent that accomplished the magic trick, we instead look at the relations and at another level of abstraction, the relations of relations when we start thinking of autocatalysis and autopoiesis and these circular forms of causation. These are relations of relations, and so a process-relational philosophy, I think, is well prepared to help scientists, biologists and chemists think through these complex situations that Bruce is trying to imagine with his thought experiments.

DSW: Yeah, okay, thank you, that's great. So, I'm going to initiate Act Two with a little thumbnail description of multilevel selection and major evolutionary transitions, and this begins with Darwin who noted that basically anything we call prosocial, anything done for the benefit of other individuals or one's group as a whole is inherently vulnerable to more self-centered strategies in a Darwinian world. Basically, if natural selection favors individuals that survive and reproduce better than other individuals and I help you survive and reproduce at my own expense, well, that makes me a chump in Darwinian terms.

And so, natural selection within groups is favoring selfishness and cheating in all of its forms, and any game theory modeler will tell you that. Thankfully, as Darwin realized, groups of cooperators robustly outcompete groups whose members cannot cohere, and that led to the best meme I ever crafted with the other Wilson, Ed Wilson: selfishness beats altruism within groups. Altruistic groups beat selfish groups. Everything else is commentary.

So, when you look at many species, many social species, what you find is a mosaic of traits that have evolved by within or between group selection. We see selfish traits that evolve by within group selection. Infanticide is a great example. If I kill your baby so I can have my baby, that's good for me. It's not good for you. It's not good for the group. It's just plain my benefit. And, we have cooperative traits that evolve by virtue of cooperative groups outcompeting noncooperative groups. Most social species are mosaics, but, the balance between levels of selection is not static, but can, itself, evolve.

And so, every once in a while, mechanisms evolve that suppress disruptive self-serving behaviors within groups so that the group becomes the primary unit of selection, and when the group becomes sufficiently cooperative, then it qualifies as a higher-level organism in its own right. The first articulation of this was Lynn Margulis and her symbiotic cell theory proposing that nucleated cells evolved not by small mutational steps from bacterial cells, but as symbiotic communities of bacteria that became so cooperative that now they qualify as a higher-level organism.

And then, as you know, Eörs Szathmáry and John Maynard Smith generalized this to explain other major transitions: the first cells, multicellularity, the eusocial insect colonies all the way back to the origin of life. And so, the hot springs hypothesis basically fits within this grand panoramic concept of multilevel selection and major evolutionary transitions. If that weren't exciting enough, we can now see the origin of humanity, our species, in the same light, in the same light. And so, the best of our current scientific knowledge is this, that if you look at our closest primate ancestors represented by chimpanzees and actually most other primate societies, you see a little cooperation and a lot of competition.

Naked aggression in chimpanzees is 100-1,000 times more frequent than in small-scale human societies, and, when cooperation does take place in a chimp community, it typically takes the form of alliances competing with other alliances within the same community. The main context for community-wide competition in a chimp community is competition with other chimp communities. And so, there it sits. From the standpoint of an individual, why would I trust or communicate with another individual in my community when that individual is actually my competitor more than my collaborator?

And so, the main thing that happened in the evolution of our species was a major evolutionary transition. Mechanisms evolved in our ancestors that suppressed the potential for disruptive competition within groups so that the group could become the primary unit of selection, and that seems to fall into two categories. One is the savannah environment that our ancestors moved into just called for a lot more cooperation than the jungle environment. In the jungle, you can kind of find your own food. But, in the savannah, just existing on the savannah, the need to cooperate became a lot better.

And then, the second reason, factor was social control, what was sometimes called reverse dominance. So, in a chimp society, the biggest, meanest individual or alliance can just bully and intimidate everybody else. But, in our ancestors, members of a group found the means to intimidate the strongest individual, and this is represented by people such as Christopher Boehm and Richard Wrangham. It's sometimes called self-domestication, is that we bred each other for niceness, basically, that, if you were mean, we just collectively ganged up on you. If we could throw stones and do things like that, it's just not so hard for us to get rid of you if you're not a cooperator.

When we think of moral systems, getting back to philosophy, that what morality is has two faces. One is a compulsory face. We have norms for how to behave, and if you don't abide by those norms, there's consequences. You're compelled to abide by norms, so there's a compulsory face to morality, and then there's a voluntary face. I want to help you, motivated by love and sympathy and so on. The beauty of this is that the compulsory face is needed because it makes the voluntary face safe. It makes it safe to be prosocial in a strong moral system because you will not be exploited.

And so, back to niche construction, the compulsory dimension of morality creates a safe and secure social environment for the voluntary aspect of human behavior to flourish. All of this is what took place in our species. And then, apologies for the long windup. Everything we associate with culture, or, I would say the vastly elaborated form of culture in our species, especially the capacity for symbolic thought evolved as a form of cooperation because, now that we were in groups of people that were cooperating, in control, mutual restraint, now we could trust each other. Now, we can share symbols.

And so, symbolic thought and a cultural inheritance system that relies upon symbolic thought requires cooperation. This is called the cooperation-came-first hypothesis. First, we cooperated in all of its forms. And then, our elaborated ability to have a cultural inheritance system evolved as a form of mental cooperation. I'll be having this conversation with other people. We are coming off of an age of individualism as an intellectual tradition and only rediscovering how much human psychology in all of its forms is a group-level phenomenon. The early social scientists knew this better than we did before, if you go to the early days of psychology and the social sciences, people like Durkheim and those folks. They could see the concept of society as an organism better than we do.

We're only returning to that, but of course, on a much more rigorous scientific basis. So, against this background and with apologies for perhaps taking more than my share, I'd like to get your opinion as to, as Teilhard said, in some ways, we're just another ape species. But, in another respect, we're a new evolutionary process, and that makes the origin of our species as iportant in its own way as the origin of life." He asks you to imagine the bushy tree of life growing very slowly into a big bush. And then, one twig on the end of one branch begins to proliferate so much faster until, in an astonishingly short period of time, it overtops the entire tree so that the human cultural diversity is like phyletic diversity, he says.

And then, of course, it begins to in-fold and all of that. We really can think of the origin of our species using the same framework as you're using for your hot springs hypothesis. But of course, the substrate is completely different. We don't need to be talking about RNA or DNA. In fact, we can't. We have to be talking about something else as the substrate for a new evolutionary process. How would you do that? I'd like to ask each of you. Maybe begin with you, Matt, and then pass to Bruce.

MS: Yeah, well I do get the sense with Teilhard in reading The Human Phenomenon that, as he tells this story of the history of life on earth, he knows where it ends up. It ends up in the genesis of this Noosphere or this collective mind, and it's as if Teilhard wants to tell this detailed evolutionary story so he can account for the possibility of love becoming a factor in the future evolution of the earth among human beings. I think this capacity for sympathy and empathy and trust among early human beings is absolutely essential to understanding what culture is.

And, while there are examples of it being prefigured and things like the care-taking of offspring or play among mammals in some other species, so culture seems to be emergent from the capacity to feel with one another. There's an emotional component to it, but there's also this game theoretic rationality to it that allows it to be advantageous to the groups that are better at it. But, we don't want to leave out the emotional component here to look at the process from within because I think the lessons for our current world are not just going to come in the form of teaching everybody a game theoretical explanation for why the economy should be a certain way, but rather for allowing us to understand that our capacity to collaborate with one another has an emotional basis.

DSW: Yep, I want to get to that.

MS: Right. It opens the door to, I think, a more multifaceted approach to understanding our transition now as we're trying to move from not just cooperative behavior within groups because of the between-group selection, but, as a human community, we really need to go beyond these smaller senses of identity so that we can cohere at a planetary level. The universal languages of mathematics and science are a big part of that, but the reason I'm emphasizing emotion here is because I think there's another dimension to this, too, which Teilhard understood was spiritual, ultimately, totally naturalistic, but, nonetheless in this human domain where love is absolutely essential to our future evolution.

There's a spiritual dimension to this, and so I think there's a real need to build a bridge between our scientific understanding and the future of religion that would not be the same as the religions of the past, certainly not religion that is in direct conflict with so much of the scientific evidence that has accumulated over the last several hundred years, but rather a religion and a spiritual perspective that allows us to be truly human. Humanity, I think, remains an idea at this point that we are striving to realize. And so, I think Teilhard was right that we represent, as it were, a new phylum or even a new kingdom of nature. But, we're not yet fully through this transformational threshold because, whether or not we're able to achieve planetary coherence remains to be seen.

DSW: That's very well said, Matt. I'm really eager to continue that, but, Bruce, why don't you take your turn? And then, this will ... yeah, very well said.

BD: Here's an approach from very far back in deep time. One could ask the question, "What differentiates the little sludges in these pools that are undergoing cycling and molecular evolution becoming more complex fairly rapidly from all the rocks and the gases in the solar system around them?" What is going on inside of them that is different than the previous 13.8 ... well, in that case, 11.8 billion years of cosmic history? If you tease that apart ... and we did this exercise about three or four years ago. What, algorithmically, is happening in there? It came to us that the first thing was crowding. Everything was going through a transmissive membrane, getting crowded.

What is crowding doing? It's increasing the probability of encounters of interactions and reactions. So okay, that makes sense. When we place these little compartments close together, what is different about that than the external cosmos? Well, interconnection. Things can travel from one part of this unit to another discretely. Discrete nodes were emerging. And then we felt, in the cycling history of this system, a third property would emerge which would be a memory, which would start with little protogene templates that could make copies of things where we get amplification, memory, remembering how to do something for the next round.

If you put all three of these together, probability begets interconnection, begets the writing and reading of memories, which then give you even more probabilistic results, i.e., bringing things that are highly unlikely into actuality, which then binds and builds the networking and the symbolic message passing and goes and goes and goes. We call this PIM, P-I-M. We started looking everywhere for this, and it turns out that PIM is everywhere. PIM may be fundamental. It's fundamental. It's underneath Darwinian selection. It's like the progenitor of Darwinian selection.

But, what we're doing right now in this little four-person conference is we're crowded together into a virtual space so that interactions may happen. We're doing symbolic message passing and we're recording this conversation so the next time we have the conversation, we get cultural intellectual evolution because we remember a certain version of it. We can watch it. This is PIM, too. We've invented PIM devices. This is one here. This crowds things together. It has vast interconnection networks in and out of it and it has an ability to have local memory that creates a group memory. So, perhaps humans arose when we moved onto the savannah. We had to start hunting more, but we also had to compete with groups that were in motion around the savannah.

But, PIM became really important. If you called across to another individual and there was a lion coming, you better get that communication clearly. You better remember where that watering hole is and you better work at all times to increase the probability that your tribe or your individuals or babies are going to be born because you better get all of that right, whereas, in a rainforest environment, perhaps, it wasn't such a challenge. Human civilization, for it to go forward in the future, needs healthy interconnects with healthy transmission of symbols that are trustable. It needs good memories to be read and written whether they be scientific data, cultural memories. The corruption of memory can help to break down not only cultures, but civilizations. And then, together with that, we grow P. P is the likelihood that we're going to tunnel through the challenges that come through say climate change or conflict and things like that.

DSW: One of the exciting developments in the thinking on humans that's very, very parallel is the tribal scale of social organization, not just the small hunter-gatherer group. That's like your protocell. A lot of cooperation is needed there, but, in order for this culturally derived and transmitted information to be stored, memorized, it takes many heads and more heads than exist in a single hunter-gatherer group. Now, you have tribes. They share a language. They might be several thousands in numbers. They seldom exist as one body, but they do exist, and so it is completely parallel with the two levels that you identified for the origin of life.

Then, as you continue to work through human history, it's improvements in memories, you know, spoken language, written language and all of that is what's providing the memory for this to go forward. But, unless it's organized for the common good, for some common good, then it's going to fall back into some kind of despotic or disruptive situation where it's serving some more than others. And so, if you look, this is a good opportunity to fast-forward to the present. Now, we have a system that is richly interconnected, global, and works for the benefits of a few elites compared to the vast mass of humanity.

And so, it's not really the Noosphere in any optimistic sense yet, and so, what are we going to do to actually create a Noosphere in the optimistic sense of the term, that global society, a global consciousness that actually sustains all its members as opposed to being more like a chimp society in which the powerful are using the whole system for their benefit? That's a distinct possibility. I think some problem that exists with many narratives of this is to imply some kind of inevitability that evolution is just going to self-organize all the way up to the global scale, and I think that what a true knowledge of evolution tells us is that absolutely not. We really have to create special conditions for cooperation in any form, at any scale, therefore the global scale. So, I'm interested to know your thoughts on all of that in any order. Matt, why don't you go just so I could move it along?

MS: Well, I think it's clear that, over the last few hundred years in the modern period, that the economic sphere is primarily what's been driving planetary interconnection. And, in the modern period, this has been primarily a capitalist economy. There was a period when it seemed like communism was a major competitor, but now that period has ended and even China is more or less capitalistic if more centralized than the other capitalist democracies. So, we have a capitalist economy that has succeeded in what we call globalizing, right, globalization of the economy though supply chains are not what they used to be.

Nonetheless, I think what's needed now is a recognition that culture, the cultural sphere and the political sphere are also valid sources of organizational structure for a global community, which is to say that we have some ideals about human rights, but we haven't yet fully implemented those ideals, and so we need some sort of a planetary political body that would defend the rights of human beings, which includes the rights of workers. We also need an understanding of culture as something which needs to be freely available to everyone not only to learn and be educated within, but to contribute to. The cultural sphere is like education, the arts, media.

All of this stuff needs to be of value to our society enough that we would, well, for one thing, fund it whereas, right now, to the extent that education is valuable to society, it's because it produces good workers to compete in the job market. And so, I think we've allowed the values of the capitalist marketplace ... which, I should say value of the capitalist marketplace. There's one value. It's profit. We've allowed that to guide this planetization process, and what we need to do is bring in, I would say, more of a political as well as a cultural sense of how to reorganize this planetary system of human beings such that human rights and the capacity to continue advancing the human project culturally, scientifically, artistically, that all of these other facets of life besides just profit making also have a say in how we continue this human project.

DSW: Great, well spoken again. Bruce?

BD: There's something I'd like to bring in that's coming from my beloved, who's just in the Gandalf house next door, Kathryn Lukas. We've been a partnership for almost two years and we're both working on related projects, and her project has real bearing here. She asked the question, "Why is it that, with all of the technological civilization and our ability to make food and provide devices and support, that our children are less healthy by an order of magnitude than they were two generations ago?" You find autoimmune conditions, obesity. It's stunning. It's an epidemic on a mass scale, and it's not just in the United States. It's in a lot of countries.

She's asking the question, "Why is it we have outsource to the market and deprioritized making healthy copies of ourselves?" So, if the progenote prerogative is right for the planet, the only thing that actually matters is the next protocell or living cell, the next microbial community is healthier. If the next community, the offspring are less healthy, then the system is crashing. So, if our children are, by all measures, less healthy, higher suicide rates and whatnot, this is an aircraft in a nosedive situation. It's an absolute emergency beyond all other emergencies.

She's addressing it by looking at what has happened to the home. What has happened when have two wage-earning parents or a single parent, basically, the outsourcing of childcare, of nutrition, of psychology of learnings outsourced whereas, three or four generations ago, that was mostly done in the home and we raised healthier adults as a result. I'll just leave you with that, but, in a way, that kind of is the key. That's the place that we have to return to. We can figure out things intellectually. We could look at global systems and optimization. We can look at ways of breaking power structures down, but, if we can't raise healthier copies of ourselves, our future looks like you'd expect with a population in decline, in actual decline, biological decline.

DSW: Of course, that's true. I make a distinction between two kinds of complex adaptive systems. That's a key word, as you know, complex adaptive system, but there's two meanings of it that are muddled,

even among the experts are just muddled. One meaning is a complex adaptive system that's adapted as a system. An organism would qualify as a complex adaptive system, complex system that's adapted as a system. The second meaning is a complex system of agents following their respective adaptive strategies ... a complex system that's adaptive as a system and a complex system composed of agents following their respective adaptive strategies.

Now, when we say, "Oh, what we're doing is bad for the whole system, pathological for the bad system," we're pointing out that our system does not qualify as the first kind, a complex system that's adaptive as a system. But, those same behaviors that are pathological at the systemic level can make perfect sense as part of a complex system whose agents are following their respective adaptive strategies. And then, what you see in that light, you don't have to puzzle over them. They're not really pathological at that level. Someone's benefiting from them even though the whole system is being corrupted as a result including the longterm interests of those that are benefiting over the short term.

And so, unless we make that distinction between those two meanings, and of course, unless we have ways of converting a complex system composed of agents following their respective adaptive strategies to a complex system that's adaptive as a system, that's the whole problem, isn't it? The whole objective is to do exactly that. And so, that's where I think that these ideas, everything we've been talking about has been multilevel as we need to accomplish, and that's what a major transition is. A major evolutionary transition converts a complex adaptive system of the second variety into the first variety. And we should be able to use this scientific and philosophical knowhow in order to do that at the final rung.

That's when the Noosphere, Teilhard's concept of the Noosphere will be brought into fruition. I can't help but want to go back, Matt, to what you were saying about the need for this kind of psychological and spiritual inner work in addition to this outer social work. It's not as if we can provide everyone with some game theoretical strategy. There has to be some sense in which we cultivate an inner state of mind which will look and be spiritual, actually. What does that mean? It will mean, in the first place, people have the whole system in mind, at least some people do, the welfare of the whole system in mind in constructing that system. That requires not everyone, but at least some people designing the system with the welfare of the whole system in mind, in other words, a whole-earth ethic, and that's an internal thing.

What does it mean to have a whole-earth ethic? Basically, you regard the earth as sacred. It means that it's more important than you, that you're willing to subordinate your activities to it and so on and so forth. So, these words such as spiritual and sacred and worship and all these things have a truly secular meaning in terms of what we choose to respect and honor and act on behalf of, which involves not doing certain things that might benefit us within the system at the expense of others or the system as a whole.

And so, I think that this inner part is needed, as you said, Matt, as much as the outer part. I think that's what one of the metaphorical insights of thinking of cultural evolution as an evolutionary process, is that it encourages us to think of our symbolic systems as like our genes. Just as there's a genotype/phenotype relationship, there's a symbotype/phenotype relationship. What we do depends on how we think, and so, if we want to behave differently in a fundamental way, we must change the way we think. We must change what's on the inside in order for us to act in the world. And so, I think this is what's on offer, and it's amazing. It's intellectually amazing and it's so great that we're all working on it and that organizations such as Human Energy and this project is focusing attention on it. So, glad to have you involved. Why don't you guys have the final word? I felt that I've been speaking a little too much in this conversation, but why don't you guys sign off in any way that you want?

MS: At this point in the conversation, reaching our present predicament as a species that it really is a question of meaning. The universe and the evolution of life have gradually been creating the conditions for the possibility of free human action where that free human action would be motivated by love and

driven to co-create meaning together like using this symbolic matrix within which we are embedded, and it's a very exciting process to be involved in. I think it's alluring enough that, if we're able to tell this story, if we're able to tell the whole evolutionary adventure in a mythically potent way, I can't imagine that people won't want to come along for the ride. So, I'm grateful for the work that you are doing, David, with The Human Energy Project and really happy to be in dialogue with you and Bruce today.

DSW: Teilhard leads the way not only in this scientific idea that he grasped so early and so well, but in his prose, which is so inspirational. He was such a gifted writer in addition to a thinker. Bruce?

BD: Yeah, I think in reading his work, what I get from it is a great sense of optimism that we will break through, that we will, in a sense, achieve our concrescence, tip to Whitehead. But, I want to suggest that, if you look back at the long scale of life, jump back to those pools 4 billion years ago when you see these wobbly little things that barely have any life in them and then you look at the earth, and they transformed, they went on to transform the earth against snowball freeze-overs, asteroidal impacts, acidification, whatever it was, the huge number of things that were thrown at life and that life surmounted these challenges and then transformed the earth into a garden world and oxygenated the atmosphere and all those sorts of things and then this incredible emergence of humans.

My spiritual sense about all this, especially as it becomes more densely interconnected, as there's more memory to draw from, that there's more potency in the overall system, that, when we put our minds to things and we put our clear intention on something, it carves open channels through improbability to stupendous results and that our minds are able to do this. Our minds and our bodies and our interconnected civilization, when it gets a concept of where it wants to go, it can carve its way forward against all odds, you'd say. And that perhaps we are, in a sense ... We are becoming the omega point. It's waking up.

You look at how rapidly things can now happen through our agency and that this is natural because this is what was happening in the progenote period as innovation piled upon innovation, as sharing increased, as robustness increased in those systems, leading to the first living cells and then that long run, and the same process is happening. And then, perhaps, humanity, in concert with the biosphere that we're transforming is becoming almost like a new meta-organism. We talked about that and we alluded to that, that there is a human organism that moves as a unit to its own survival. As individual members, as individual protocells of that organism, we can't see it. We can't understand it.

But, our species, perhaps the biosphere itself is acting with the intention of making it, the intention of pushing to higher complexity, self-regulating its systems better, curing its little tummy ache that it's got and perhaps colonizing the near solar system, perhaps being able to do that first budding, that first fission event where it creates new worlds, where the earth divides or Gaia divides, that this is perhaps all happening within us, each of us, and it's happening in this meta phase that we can't sense, but we know it's there. We can't measure it. It's just a force. It's a 4 billion-year-old force against all odds. It shows no signs of stopping, but what a ride it is.

DSW: All right, so, excellent ride. Our conversation has been an excellent ride, gentlemen, so, thank you. This is another great contribution to this Science of the Noosphere series that's building. So, thank you very much again and I look forward to continuing to interact with you.