Originating Life: Six big questions
Holmes Rolston

Post-Lecture Discussion

The Origin of Information

Participant: I'd like to put in a thought about where information comes from. I don't think it is as mysterious as you are making it. Information comes when you condense second and third-generation stars and solar systems, you have in there the atoms made from hydrogen and helium by nucleosynthesis and supernovae explosions. As a result of that and the Pauli exclusion principle then you have the periodic table. All of chemistry emerges from physics by the one symmetry principle. Once you have the periodic table you have information. It's abounding because now you have all chemical possibilities, then you have information. I would argue that that's embedded in a principle all by itself. It's an extra-quantum mechanical principle, it's a nondyamical principle, but the Pauli exclusion principle gives you chemistry from physics and that introduces information into the subsequent world.

Holmes Rolston: What that means is you get the chemical table out of the stars. If you take off anywhere in the universe you take the periodic table with you, you're going to need it. But the biologists don't necessarily think that you need to take your biology textbook off everywhere else in the universe. They think the biology is going to be unique to earth. Nothing about those mitochondria and chloroplasts is written into the Pauli exclusion principle or the Big Bang.

Participant: No, there are some of us who think that if you take the metabolic chart you can derive that from the periodic table, and this would be a principle, a law of biology that is embedded--and exactly where it is coming from we don't know cause we don't have the equivalent of the Pauli principle yet. But that metabolic chart is 4 billion years old. It's not that the number of intermediate molecules has gone explosive. The core of the intermediate molecules, the 600 or so core of that metabolic chart has been blocked in for 4 billion years and has been absolutely robust in spite of all genetic changes and so forth. So I think there are principles and laws of biology that enter into the origin of life that we're not focusing on.

Holmes Rolston: But you don't think that mitochondria and chloroplasts are forged in the stars. You don't think diploids and haploids are forged in the stars.

Participant: I think there are a hierarchical series of emergences and at each stage some things emerge, and it's our task to find out what those emergences are, what the laws that govern them are, and to explain life in those terms. But at the level of chemistry, which is the huge level for biology having those elements, and also in the Pauli principle is the covalent bond, metallic structure, crystal structure it's all in that one principle.

Holmes Rolston: Do you think that genetic coding is written in the stars?

Participant: I want to have a series of hierarchical steps at which novelties come in because you're in different domains. They come in because there are principles. I don't know where those principles are written, they're written in the mind of God. I mean, I don't feel obligated to say whether they were written into the Big Bang. But certainly the Pauli principle, we have this one super example of a simple symmetry principle which generates all chemistry from physics. And that should give us great encouragement to go on and look for similar principles as we go into the structure of the origin of life.

Probability, Possibility, and Contingency

Participant 1: One of the reasons NASA is interested in this field is because one of the ways you can find out what the probability of what happened here is to go somewhere else and see what happened there. So the whole idea of whether we are a high-probability event or a low probability event can be informed by checking out one of the other dealings. Like in a card game, who got a royal flush and who got nothing much. And so it's important to realize that we are just at the beginning of a possibility of understanding that.

Certainly many biologists don't believe that it is all contingent but there are evolutionary principles that shape what has happened here. Even if you go into the symbiotic events in your presentation as two isolated events; there were many more symbiotic events than that but you just haven't mapped them. Ford Doolittle and others would say, the bottom of this doesn't look like a single pipe at all, it's a web of interrelationships and gene transfers that has happened forever and we only simplify it because we are just beginning to realize how much of this has gone on back and forth between different organisms in the past.

We are not even capable of discussing this intelligently given what we know about what happened here on earth. We certainly aren't in a position to understand how it might have gone elsewhere with the same basic carbon chemistry and physical conditions. But we should beware of making judgments that what happened here is the only way it could happen.

But we're also in a bad position if we say that it can't happen this way exactly anywhere else. We have to be constrained by those two boundaries.

Participant 2: Will you repeat the boundaries?

Participant 1: We're totally unique; everything is like us.

Participant 3: I would agree that there isn't any anthropic principle. But it's not just biophilic. The necessary conditions for the development of life, particularly for the development of evolution, required a very special initial condition in the universe. I think you are right that there isn't a principle, but I do think that fine tuning, or the claim for fine tuning, is at least a claim for certain necessary conditions and they bear on what we

are talking about here. Necessary conditions involve planetary life, but most especially the time sequence that would be needed for evolution.

The other point I wanted to suggest, the notion of possibility is very complicated.

Holmes Rolston: Yes, indeed it is.

Participant 3: And I think that the point that you are making is that possibilities that are present in the beginning are not present in the historical sequence.

Holmes Rolston : Yes, you shut out some possibilities. But when this happens you can also open up new possibilities.

Participant 3: Forks are taken and from then onwards, possibilities change. But this is not to say they weren't there originally. History has a way of completely altering possibilities. I think that's where contingency comes into your story. If you look at the question of possibility, it's important not to look at some segment, like DNA alone or RNA alone, there's always a much larger question of environment. It's not so much information.
If I were going to put a plus in here I would say, plus environment because the environments can change. And in a different environment, for example, an environment on earth that didn't contain calcium we'd have a very different sort of secretion. The environment has a huge effect on how these possibilities work out. So when you talk about possibility, it's not about the X, whichever that might be on the RNA, but it's the RNA placed in a particular historical environment and the particular resources available to it.

Possibility is a large thing there. It's not logical possibility, it's what you call physical or empirical possibility. What you are emphasizing is the sources of contingency. In other words, what you are arguing against is an overstatement of the inevitability in the environment of the development of life.

Information Generation and Intelligent Design

Participant 1: Listening to you I was struck that if one substituted intelligence for information what seems to be your argument is fairly similar to that of the intelligent design people. Am I way off?

Holmes Rolston: I don't consider myself to be an intelligent design person, no, because they have too much tendency to believe in intervention. They deny that these processes can be incremental in some way. I don't want to deny that these steps were there and these processes were incremental. But I am still puzzled by the generation of new possibilities by the appearance of novel information. I'm shy of the word "design" but I can't escape the belief that there's been a generation of information that's quite surprising.

Participant 2: Can this information emerge naturally?

Holmes Rolston: I didn't address that question. It wouldn't surprise me if the appearance of that information had something to do with divine inspiration. That's not something biologists could ever figure out. I'm not going to say whether the supernatural is required. If you don't need the supernatural you are going to have to start spelling "nature" with a capital "N" maybe. You're going to have a Nature that has a surprisingly cognitive element in it generating information. But you've only got one planet in which we're sure this is happening.

Participant 2: It would seem to me that the real issue here is not so much where the opportunity for intervention comes or that there's intervention but where it comes. If all information is found in how the universe turned out subsequent to the big bang, all the information flows from what's already there. The action of the mind of God is put off into a different frame altogether. I think it's likely that all the information we've developed, with buildings and people and what not, really does trace all the way back to the beginning of the universe.

Holmes Rolston: I think that is a very deep article of faith. I don't get any evidence at all that information on how to build a computer was lying around somewhere in the Big Bang.

Participant 2: I didn't say it was lying around. But it devolves from that. If you take a look at the manufacturing process in general, there are many things that are manufactured today that couldn't be manufactured at all unless you have a long history of technology that goes back to some guy chipping a rock.

Holmes Rolston: But there is the building up of new information, which wasn't there before.

Participant 2: Well, we're losing some information. There are things we can't make anymore because we've lost the thread of the manufacturing process and they are no longer extant. So someone developed that information by innovation in the first place.

The Origin of Biological Information

Participant 1: I guess I also don't understand why the origin of biological information is such a problem if we think of it at a slightly later level than what Harold Morowitz was talking about, that is, where biological information is information coded in the genetic material. What we know experimentally is you can have one little tube of RNA composed of random sequences, and in those random sequences there are molecules that can do any biochemical function that you can name. A bunch of those molecules can bind to different things, catalyze different reactions, and the potential is all there in a relatively small sample of possible sequences, so it's not that hard to generate information that can have a selective advantage.

Participant 2: The distinctions about information might be important. I wonder if there is the Shannon/entropy idea of information, a thermodynamic differential, and then there's information as code. It seems like even though information as code is ultimately directed at maintaining a thermodynamic differential, it does look like it might be different enough information to make a distinction. In other words the information is coded it may not be as difficult to get as this thermodynamically based idea of information.

Holmes Rolston: If you have salt, sodium and chlorine, and you put them together you don't need a lot of information to make salt. They just go together automatically to make that.

Participant 3: You need the Pauli exclusion principle.

Holmes Rolston: But if you have carbon and sulfur and hydrogen and oxygen and put them together to get a coyote you need a lot of information. It does seem to me that biological information is new in the world. Maybe you can't get it so easily.

Participant 1: But Darwinian evolution generates that information.

Participant 2: Information as code.

Holmes Rolston: If you do find that you get information easily in the laboratory experiments, you need to recognize that you get it easily, only after going to a lot of trouble and time setting up the laboratory in which it can easily happen.

Across most of the universe such generation of information doesn't happen. You have to go out in a spaceship and search hard to find where it has happened. You have to have, as Ernan said, an environment that is conducive to the eliciting of that kind of information. Everyone says you have only one data point on earth. It does seem to me that something special has taken place on this planet, and it doesn't look to me like it routinely happens elsewhere in space.

Information, Planet Formation, and the Big Bang

Participant 1: Not long ago we debated whether or not this solar system is unique or whether planets actually form commonly in the process of star formation. In the next 10 years we're going to confirm that the answer is that the information on how to make planetary systems really was part of the Big Bang and it happened when stars formed and there were planets all over the place. We have pretty much already had this discussion and concluded that the information about how to make planets really was there from the Big Bang.

Holmes Rolston: True, but you don't need any genetic coding to make planets. You make those like you do salt out of sodium and chlorine.

Participant 1: But you need a whole lot of chemistry and physics.

Holmes Rolston: I think it wouldn't bother me to possibly discover that the planets are made about like sodium and chlorine together to form salt. Stars spin around and form planetary systems. You seem to be using the word "information" in a different sense from the way I'm using it biologically.

Participant 1: I think the commonality between the way I just used the word "information" and the way you used it is the sense of underlying laws and principles. And whereas we know what those underlying laws and principles are in physics and chemistry, we don't yet know what they are in biology.

Participant 2: Yes we do.

Participant 3: We don't know all of them.

Participant 2: We know the overriding principles.

"Unpredictable surprises" and Convergent Evolution

Participant: I want to get away from information for a minute and talk about your comment about unpredictable surprises, and how the diatoms came after the arthropods instead of the other way around. I was surprised that you were surprised because this is a perfect example of convergent evolution. You have silicious spicules in sponges, you have silicon in diatoms, over and over, and the same in carbonate, over and over. And the fact that organisms learned how to use it must be trivial because it has happened so many times.

It also seems to me that you're reversed what's going on, by saying that by going to the next step you are generating new possibilities. You are not opening up new possibilities, but rather you are actually eliminating possibility space each time you take the next step. In biology it's called "penalization." Once you've taken one step you've limited the possibilities for the next step. It may look locally like you've opened new possibilities, but you've now eliminated other possibilities, so you're channeling to more and more focus.

Holmes Rolston: True, but while we are giving up possibilities, certain historical trajectories take place but not others. But don't you think you're also gaining new possibilities, as when the mitochondria or chloroplasts appear?

Participant: No, I think we are far more limited in our possibilities. We have a history of fewer and fewer possibilities as we progress. Pretty soon we will converge on zero possibilities.