Extraterrestrial Life
April 14, 2007
2:30 p.m.
The Philoctetes Center

Levy:	**Francis Levy**
Ferris:	**James Ferris (moderator)**
Dick:	**Stephen J. Dick**
Fischer:	**Debra Fischer**
Itzkoff:	**Dave Itzkoff**
Loeb:	**Avi Loeb**
Marusek:	**David Marusek**

Levy: I'm Francis Levy, Co-Director of the Philoctetes Center, and welcome to *Extraterrestrial Life.* All week long I've been waiting to say that phrase because the Philoctetes Center is so terrestrial in its gravitation, in its use of communications media, cell phones, internet, fax, we are firmly linked into the terrestrial world.

I'm pleased to introduce Jim Ferris and welcome him back after having been a participant in the *Origin, Evolution, and Future of Life on Earth* panel, which was very successful. James Ferris is Research Professor of Chemistry and Chemical Biology at Rensselaer Polytechnic Institute and Director of the New York Center for Studies on the Origins of Life. Dr. Ferris will moderate this afternoon's panel.

Ferris: Why don't you all introduce yourselves and Debra why don't you start?

Fischer: I'm Debra Fischer. I'm a Professor of Astronomy at San Francisco State University and my research is on the detection of extrasolar planets—planets around other stars.

Dick: I'm Steve Dick. I'm the NASA Chief Historian. I've been writing about the history of this debate on extraterrestrial life for the last thirty years and I still haven't run out of things to say.

Loeb: I'm Avi Loeb, Professor of Astronomy at Harvard University. I'm working mostly on the early universe and how the universe started, but recently became interested in extraterrestrial civilizations.

Marusek: I'm David Marusek. I'm a science fiction writer and extraterrestrials are part of my beat.

Itzkoff: My name is Dave Itzkoff and I write a column for the *New York Times* Book Review called "Across the Universe," which is about science fiction and other kinds of speculative fiction. I have a Bachelor's degree in English.

Ferris: Thank you. What I was thinking of doing today to get things on the same sort of platform is to talk about what life is. We're going to be concerned with extraterrestrial life, but how do we define life as we know it here on Earth? And then we can go from there to talk about the potential for life in other places. Could you quickly come up with a more or less all-inclusive way of saying what is life basically?

Fischer: You're starting with the hardest question.

Ferris: It is, but I think we need to start there. And then we can go on to talk a little bit about the characteristics of life as we know it here on Earth. Is anyone on the panel willing to jump into this quagmire?

Nersessian: But you are the one who gave a definition of it last time.

Ferris: You remembered. Okay, I'll start. The very simple or basic definition as I see it is a system that is capable of replication with change. There's a one-sentence definition of life. Let's take it a step further. Once we have that definition, it's hard to put anything on it, like what the living things do. We could try to go into some sort of characteristics. Does life communicate? How does it maintain itself? Let's start with that. As a living system, what do you do?

Loeb: I'll mention just two brief comments from the point of view of an astronomer. The first comment is that when everything started, when the universe started, there was no water around, there was no oxygen, and there was no carbon. We are sort of an afterthought—the existence of life came about after stars burned hydrogen and made heavy elements. And one of these stars is the sun and there was some debris left over from the formation of this star—some pieces of rock, one of which is the Earth. On the surface of the Earth, there was liquid water that allowed chemical reactions to take place and to end up as complicated, complex molecules that allowed organisms, like we are, to exist. So it seems circumstantial that complexity came out from the very simple initial conditions of the universe. But it's not something that was pre-planned—it's not like the universe was designed for us to exist in it.

Now the question is: are there other places where there are circumstances similar to that? The first thing that comes to mind is that it requires liquid water. So are there other places where we can find liquid water—other pieces of rock near other stars that have liquid water? Can we find evidence of that in our solar system, for example? Or can we find evidence for complex life as we know it in the way that it affects the environment, like the atmosphere, by observing other planets around other stars? That's the common view that astronomers have on this subject.

Now, it's also possible that there is life out there in a very different way that we are not imagining. We often think about it in the context of our environment here, but you could imagine that instead of water, perhaps ammonia can be used to support complex molecules to make chemical reactions that take place and so forth. But that's well beyond our ability right now to explore. The issue is really whether we can see evidence or look for life similar to what we find here.

Ferris: So you're saying that there could be other forms, but you feel that water is very important in this whole process.

Loeb: If we just assume that that's the generic way of making life happen.

Fischer: You asked what these systems do and I think there's such an incredible range—from plants that certainly don't communicate to creatures that have some sense of self-awareness and communicate and have egos and look for life elsewhere in the universe. So it's tough to define something and I like the idea of sticking with stuff that's observable, starting with what we know. So we could speculate, as Avi said, that there's life in ammonia as a solvent for life, that there's silicon-based life instead of carbon, but we know that carbon is one of the most abundant elements in the universe and that carbon is capable of a range of molecular bonds, unlike silicon. Double-bonding and triple-bonding is easy; long strings of polymers. A carbon base seems like a really good place to start, if you're going to define a box where you're going to look: carbon life and water as the ideal solvent. So I agree with those two materials.

Ferris: So you're saying that we should start with what we have here and then go from there. But the basis of this society is imagination and I don't want to leave that out because that's why we're here and that's one of the objectives. Maybe don't make that box too small.

Fischer: Okay. But one of the things is that a lot of the tests that we design to look for life are very specific and they test for the things that we know. And so we're going to miss a lot of the exotic things, I'm afraid.

Dick: I'll say something about imagination because historically, if you look back, there's been an interest in this subject going back thousands of years, to the ancient Greeks, and even before. But the interest up until the last century or so has almost entirely been in extraterrestrial intelligence. Everybody had their own idea of what extraterrestrial intelligence might be. Kepler, for example, believed there might be intelligence on the moon because he saw a perfectly circular crater—this is right after the telescope was discovered—and he thought they must be made by "cellanites," as he called them. And he thought they would be sort of troglodytes who had to live under the ground because he realized the temperature there would be very hot. And there were others who had a bigger idea that the closer you got to the center of the universe, you would have beings who were more sublime and subtle. And so there has been a lot of imagination, especially in terms of the extraterrestrial intelligence debate. I think only in the last century have we really gotten down to the scientific questions of the origins of primitive life, which are really what the astrobiology programs and most of the research these days are about. There is, of course, a SETI component, which is no longer funded by the federal government; it was outlawed by the government in 1993—or the funds were cut, anyway.

Farris: It's not outlawed—it's allowed.

Dick: It's allowed, but not with federal funding—that's right. That is an ongoing program, but not within the federal government.

Farris: Well, since you brought up intelligent life, maybe we should take a crack at that. How do we define intelligent life? Could you give us your feeling on how you would define it?

Dick: Well, the SETI people have an operational definition—it's a technological civilization from which you can get a communication—a radio-communicative civilization—because that's the way we think you have to detect them. And some of you may have heard of the famous Drake Equation, which is the number of radio-communicative technological civilizations in the galaxy, which Frank Drake came up with in the early 1960s. I don't want to get sucked too much into that equation, but the answer really depends on what assumptions you put in. Some people come up with a billion technological civilizations in the galaxy that might exist and others come up with one. I always say that you have to be careful or you'll prove that *we* don't exist.

That's the main way to search for intelligence these days and so that's sort of the operational definition that's being used.

Loeb: There are several times that you mentioned already that people define things based on the ability to answer questions scientifically. So the idea is that you define something in a way that allows you to actually do an experiment and see if it exists. There may very well be things that we don't imagine and that we will never look for. But that's the way that science makes progress—we imagine something that we can do an experiment on and we do the experiment. If we find the result that we anticipated, that's very nice; if we don't, that's also telling us something. That's the only way to make progress.

Ferris: You made the statement that plants don't communicate with each other. I think an argument could be made that they do. We won't go into that, but they do give off compounds that affect other plants of the same type. There are examples of that, but I guess that doesn't fit into the definition of intelligent life because it's not technological.

Dick: No, not into that particular definition. I do think we need to bring in imagination here. I wrote a book called *The Biological Universe*, meaning that if the universe is full of life, rather than us being the only life, then it's quite different from just a physical universe where you have planets, stars, and galaxies. If you have a universe full of life—you have life, mind, and intelligence—that's called the biological universe and that's normally what we mean when we talk about carbon-based life. But I've also pointed out that you really need to take cultural evolution into account because 10,000 years ago, we were not very different biologically from what we are now. We are very different now in terms of cultural evolution than we were 10,000 years ago. So I would say that you have to take cultural evolution into account when you're talking about extraterrestrials.

I've come up with an argument that maybe the universe is not the biological universe, but a post-biological universe, by which I mean that it may in fact be artificial intelligence—and then this gets you into all kinds of arguments about strong artificial intelligence versus weak and whether it's even possible in principle. But we don't think in long enough terms—life could be billions of years old. It could have evolved long before we did. And the question is, where does cultural evolution take you after a million or a billion years, much less 10,000? One guess, which I think you could make arguments for, is that it would no longer be biological because any civilization that can improve its intelligence will improve its intelligence; one way to do that is with artificial intelligence and there may be other ways, too.

Loeb: It's not clear to me at all that intelligence is a guarantee for survival, that it's something beneficial, because first of all, if you look at politics these days, it's clear that we may end up in a nuclear war or some event that will eventually terminate life as we know it. Moreover, if the conditions change—for example, if the star changes its properties—intelligence is very fragile, it's very sensitive to the exact temperature on the surface of the planet. And you may have crocodiles that are very dumb and can adjust to changing conditions and that prevail and exist much more out there in space than intelligent beings. So intelligence may be short-lived; it may be a phenomenon that we are encountering now that will not survive for much longer. We shouldn't think of it as the ultimate thing that is actually promoting survival. And it may be the explanation for why we haven't yet seen evidence for intelligent life out there, that it's a short-lived thing—a phase—on our planet. There are many speculations you can make. And the issue is really how to do an experiment that will teach us whether they are out there or not. How can you check for that?

Marusek: Well, as a science fiction writer, intelligent extraterrestrials are what we're interested in because dumb, unintelligent life is hard to weave a story around. You can have a solar-system-wide cloud of fungus that drifts through the universe and eats planets, but that, at best, is just a background element in a story. You kind of have to have intelligence in order to write a story.

Part of the Drake Equation is what the technological level of this possible civilization is. Because a billion years ago civilization may have been sending out messages—broadcasting messages—but they went by us a long time ago.

Dick: It's not the level. There's a parameter called "L," the lifetime of a technological civilization. And so this is where you get into cultural evolution and how long the culture will evolve before it destroys itself. And that is the biggest uncertainty in the entire Drake Equation—its "L." We've been a technological civilization for only about a century if you talk about a radio-communicative technological civilization. You can put a century in there or you can put a million years or a billion years, and right there you've got a factor of 10 to the 9^{th} or so.

Marusek: Well, maybe not to do too much on SETI just yet, but isn't it true that SETI people are moving into other areas or looking for other things besides just radio telescope signals?

Fischer: Optical SETI.

Marusek: Optical SETI, right. I've read there's an idea that intelligent societies a billion years ago, who may have already become obsolete and extinct, have possibly set up archives that are intended to be broadcast indefinitely, or have sent artifacts to park themselves at the Lagrange points of various astral bodies so that millennia later, other civilizations can find them.

Loeb: I should say that if you were to ask whether we are visible to the instruments that have been used so far to search for SETI, the answer is no, because all the searches that were done so far were at frequencies well above a gigahertz. If you do a radio search, you have to define the frequency. Most of the television and radio broadcasting and military radars are done below a gigahertz. If you open your FM dial and look at it, it has hundreds of megahertz. There was never a SETI search at the frequencies that we are transmitting at. So in fact my interest in the subject was to point out that we are now developing instruments that will help us to image the early universe and the same instruments are operating at a hundred megahertz. So for the first time in history, we are able to actually eavesdrop on a civilization that is similar to ours and it's never happened before. So the point is if you go away from the Earth, how are we visible? For example, we have TV, radio, and military transmissions and we have been doing that for fifty years. It turns out that these instruments that are now being built can see a planet like the Earth from a distance of fifty light years.

Marusek: I've read—I'm not a scientist, so I really depend upon you guys as experts—that the signals that we send out inadvertently—TV, microwave, and such—are such low power that they really wouldn't be much detectable beyond fifty light years?

Loeb: Well, that's my point. So now we are building actual instruments that can see for the first time at distances of tens of light years and, with future extensions of these instruments, you can go to hundreds of light years. That was never done before. And these instruments will be operational within a couple of years. This is a new development. And you just get the data from the sky that you get otherwise, for other purposes. You just need to process it. It doesn't require any major investment to fund; the data will just come. These instruments will be able to set new limits on twin civilizations similar to ours for the first time. That was never done before. So we were looking for other civilizations at frequencies that we are not transmitting at.

Dick: Well, it depends on what the power is of the detector on the other end, of course. If you've got a huge interferometric radio telescope, you might be able to hear a lot more than if you have a small one. You always hear that they're out there getting our "I Love Lucy" programs, but that would not be very easy to decipher.

Itzkoff: Do we know with any certainty if there were other civilizations that they'd have to be using any kind of radio—

Loeb: No, because we are developing now, for example, cables. So you have digital television that doesn't transmit anything. So, in fact, the old technology that we used to have, in particular the ballistic missile radars, the warning systems that we used against the Russians, these were very powerful and they were just broadcasting out. And all we can hope is that within fifty light years, there is nothing hostile because it's looking back at us right now. We have been careless in terms of how much we broadcast out.

Dick: But it's the great game in SETI to figure out—you've got 10 billion radio channels to figure out which channel to tune into. It's not easy. So what you can do is tune into millions of them at a time—that's what the SETI program does now—but then you have a lot of channels to look through and figure out where to look. You've got a lot of places to look.

Loeb: But the antennas, the hardware of such a SETI instrument, at low frequencies, are just dipole antennas that you can buy at RadioShack. The idea is to put a lot of them—10,000 of them over a square kilometer—and then you get enough of a collecting area.

Marusek: Is that similar to the Allen Array?

Loeb: Yes, except the Allen Array, again, is operating close to a gigahertz and above. But these other observatories are operating between 80 and 300 megahertz, which is just where we are transmitting.

Marusek: You mention that we would hope that there would be no hostile listeners within fifty light years. How many solar systems would that encompass?

Loeb: Well, first of all, you can easily answer the question of how many stars are out there. So within about several tens of light years, you have about a thousand stars. As you go to a factor of ten more, you get a thousand times more stars—you can get millions of stars. Now the question is what kind of planetary systems do they have? Do they have an Earth-like piece of rock orbiting one of these stars that allows liquid water to exist? You need the rock to be at the appropriate distance from the star so that the temperature on the surface will allow liquid water. If it's too close, water will evaporate; if it's too far, it will become ice.

Marusek: Which gets us back to the question, what is life? What do we need for life?

Ferris: Maybe we could go to some specific examples. We've talked about the Earth. Let's take our solar system—where are possible places where we might find life just in our own solar system?

Loeb: Europa is a very good sign.

Fischer: Europa is one of our best bets, yes.

Loeb: There seems to be a layer of ice on top but then, underneath it, there may very well be liquid water. Well, the question is whether there are fish.

Ferris: Well, I guess you could say that. Europa is a moon of Jupiter; Ganymede and Callisto have similar properties. So they are possibilities also. How about our favorite place that we keep worrying about these people coming after us—Mars?

Dick: Historically, Mars has certainly been the place to look, starting with Percival Lowell in the late nineteenth century and H. G. Wells' *War of the Worlds*. I'd have to say, looking back over the last fifty years, that the search for life on Mars has certainly been a driver of the space program. NASA had barely been founded in 1958 when they had on the drawing board the space craft to go to Mars, to be the first to do reconnaissance with Mariner 4, and eventually to land the Viking Landers and look for life. That's still controversial to some people, whether they found life or not. The consensus is they didn't. But now with all of the Mars Global Surveyors and the Mars Exploration Rovers that are over there, they've revealed a lot about past water on Mars. And so Mars remains very active as a possible exobiology site.

Fischer: Even subterranean water right now. And I think it's interesting that the first place we both said as our favorite place for life in our solar system is a place that's outside the habitable zone. And so thinking in terms of the classic habitable zone as not too far, not too close, is maybe too narrow.

Dick: The habitable zone certainly has expanded from what it originally was.

Ferris: I think that's the one thing—it was very narrow at one point, but if we look at where our life is on Earth today, we've expanded our view of that. I don't know how many kilometers down you still find life. There's no solar radiation or anything like that.

Dick: That's extremely important, the point he's bringing up. Life in extreme environments—I'm particularly interested in it because I have a son who goes down in the Alvin to the bottom of the ocean and looks at these hydrothermal vents, these black smokers, and you find these tube worms and you find a profusion of life down at 10,000 feet, at extremely high pressures and temperatures. That tells us something about the possibilities of extraterrestrial life—the conditions are much broader than they used to be of where life can exist.

Ferris: And you find life in ice and in other places like that, too. How about other bodies in the solar system? I'm being the professor here, I guess. Be imaginative.

Dick: Well, if you want to be imaginative, there are people who still think there is life on Venus. Venus is 900 degrees and it has sulfuric acid rain, but there are people who say there could be life at the appropriate level. Or even on Jupiter—one of Carl Sagan's favorite life-forms were the gas bags floating in the clouds of Jupiter.

Itzkoff: Right, or on a neutron star.

Dick: Well, there have been science fiction novels written about that by Bob Forward, for instance.

Loeb: An interesting question about this is whether there is a continuum in terms of the complexity of chemistry, ending up with life as the most complex chemistry that we can imagine. But then it's just a quantitative question as to whether life developed in some sites or not. And you can have complex chemistry—we know that—in very different sites. So what is so special about life compared to just other chemistry?

Ferris: That's yet another question. How about comets? How about asteroids?

Fischer: Extreme changes in conditions—you can be imaginative, but you can be imaginative within a box. For objects that are certainly on highly eccentric orbits where they plunge in close to the sun and then spend most of their time far away and that's very cold, those are going to represent serious challenges for life. And now you have an object that's not so big and burrowing down kilometers into a more protective environment is challenging, as well.

Dick: You have science fiction on this, too: David Brin's *Heart of the Comet* and other novels have been written on that. One of the big discoveries over the last few decades has been the distance of complex organic molecules in these giant molecular clouds in outer space, up to the level of amino acids. There are amino acids floating around out there; that's not life, but it's a building block of life. It depends if you're an optimist or a pessimist. If you're an optimist you'll say that there are building blocks of life floating all around the universe, but if you're a pessimist you'll say that that's a long way from life. That's the big jump.

Loeb: There was actually a scientific paper on this subject; it's not just science fiction.

Ferris: You should defend your area.

Marusek: We're used to this.

Loeb: The solar system as we see it now was not like that when it formed. There were many more objects in it and they were kicked out because the planets that we see now are more or less on stable orbits—stable within the lifetime of the solar system. There were many objects that were around between the planets that were kicked out. And in fact there was a *Nature* paper, a very short one by Dave Stevenson, about whether life—if it existed in one of these bodies that presumably were small and perhaps were close to the sun—would survive if they were kicked out. Obviously, you lose the heat source—the sun—but you can have radioactive decays within the object and he calculated that, in principle, in the deep interior of such objects that were kicked out, life might survive. So it's just like a spaceship moving through space, inside of which you might have life.

Ferris: Well, they do know that in the case of asteroids, that they have undergone reactions in the inorganic compounds, which have changed them. They can see that this is like an erosion process. So chemistry—water—has been acting in these asteroids. Maybe there was a long enough time for life to have evolved there. There are organic compounds—it's a real mess of organic compounds—but they are there.

Dick: I should say that the skeptics historically have been very critical of this kind of argument. They say you spent a billion dollars to go in search of life on Mars in the Viking Landers and you didn't find it on the surface. So now what do you do—you say, well, it may not be on the surface, but it's underground somewhere, so now we have to go look for that. And to an extent, it's a public policy question because taxpayers' money is spent to look for those sorts of things.

Loeb: Well, if we visit one of these planets enough we will contaminate it with life. Life will be found eventually.

Dick: That's another question, contamination and back-contamination, yes.

Itzkoff: From what I've read, among science fiction writers, even though they produce this for a living, they don't all necessarily agree or take it as a given that there is other life in the universe. A writer like Michael Crichton, who is maybe not the best representation of a science fiction writer, but certainly one of the most successful, gave a speech a few years ago and he basically equated SETI to a religion. He is very much opposed to government and even private support of SETI. He feels it's a waste of time.

Loeb: But why is that a religion if they are just making observations?

Itzkoff: I don't know—there are a lot of things that Crichton says that I don't necessarily agree with.

Dick: There's a new book out by George Basalla, who is a historian of technology, and it's called *The Civilized Universe.* He says that SETI is like deities for atheists because it's a kind of religious search, a search for a superior intelligence.

Loeb: But suppose they don't find it—it wouldn't mean that nothing is out there. They're not believers; they're just doing an experiment. The way I define the difference between religion and science—there are two differences, actually: one of them is that science doesn't have answers to all questions; the second one is that in science you don't have a prejudice—at least, you shouldn't have. So if the SETI people are doing their observations without prejudice and they are just looking out, setting limits, and not finding anything, it's not a religion. They can change. They may decide that there is nothing out there.

Dick: There are people, though, who would rather that we not look because of the possible implications. I just came from a conference where we discussed this. This has been discussed for 500 years—what the implications are if we find life, especially intelligence.

Loeb: You're saying it's better to be ignorant—

Dick: I'm not saying that, but some people are saying it. And there's no consensus on what the impact would be. At the meeting I was just at we had somebody from the Vatican observatory—a Jesuit priest— who said he thought that if extraterrestrial life was discovered that the Catholic religion and Christianity in general would somehow adapt to it because the alternative is extinction of the religion, which is not going to happen. But there may be a need for some real adaptation.

Loeb: But as far as I can hear from religious people, they would say that God created the other creatures, as well.

Dick: But you have big problems with redemption and incarnation in particular doctrines like that which are directed towards the Earth.

Marusek: But that does raise the question—why is it seemingly so important to us to know whether or not there is life in other places?

Dick: I think it's because it defines our place in the universe. It's a very different universe if it's just a physical universe where we're a fluke, or if it's a biological universe, which is full of life, or a post-biological universe. It's very different for long-term human destiny, whether it's our destiny to go out and populate the universe or whether it's our destiny to go out and interact with extraterrestrials.

Loeb: But if you think of it as chemistry, then it's nothing special.

Marusek: Okay. Well, thinking of it as chemistry, there would be a difference, say, if we found life in Europa and it was not based on DNA as opposed to if it was, correct? Because in the one case, if it was not based on the same sort of chemistry as us, it might lead us to believe that life could be very widespread throughout the universe.

Itzkoff: As a scientist, do you still leave that door open that maybe life can exist without DNA?

Fischer: No, but maybe with a different DNA. DNA is so important for replicating that I wouldn't dismiss it, but I think one of the most interesting questions—and I don't know the answer to it—is whether or not life on Earth had a single origin or whether or not, over time, it was eradicated by collisions, for example, and then restarted again, and whether there was more than one spot on Earth where life started.

Loeb: There is also the issue of uniqueness. Is life as we know it the only possible life? And if we find lots of other variants, it's very interesting to realize that we are not unique in any way.

Dick: Interesting enough to put government money into it?

Loeb: Government money has been put into science for many other quite important questions that are similar to this. For example, how did the universe start? We had space telescopes looking at the beginning, trying to address the first chapter of Genesis in the Bible scientifically. When was the first light produced? What happened in the universe early on? These are questions that were interesting to mankind throughout history, for thousands of years. And now we have the ability to address them scientifically. That's an amazing challenge. People wondered whether there might be life in the stars out there, but now that we have the technological ability to address this scientifically, it will be a great advance for our own culture to figure out the answer to these questions. So I think we should not be too practical. We go through our life for fifty or a hundred years wondering about the big picture—what's our place? Everything we see around us, how did it start; what's our place in this big picture? And it's important for us to figure out what's going on. So government money should be spent on questions that are interesting to the public because that's who is giving the money, the public. And if the public is interested in answering these questions and the public goes to churches, why shouldn't the public get the scientific version of the story?

Dick: Well, Congress didn't seem to agree when it cancelled SETI in 1993.

Loeb: That's politics, right? Politics is not always going in the right direction.

Marusek: Along those lines, do you have anything to say about the anthropic principle?

Loeb: Recently it became very popular.

Marusek: Okay, define it.

Loeb: Okay. So the anthropic principle says that the universe as we see it has conditions that allow us to exist and in other regions that we cannot directly see right now—space is bigger than the region we can see since the Big Bang—conditions might be different. There are many versions. That's the simplest one.

Marusek: Conditions meaning gravity and the speed of light?

Loeb: No, not the speed of light.

Marusek: Weight forces?

Loeb: What physicists are now trying to resolve is that it turns out that in our universe, the vacuum is not empty. The vacuum has some energy density to it—this is called the cosmological constant. And, in fact, because of that, the universe is now accelerating its expansion. So instead of slowing down the expansion—the matter usually would slow down the expansion—it seems like there is a vacuum that dominates and that accelerates the expansion. This is something that Einstein's equations generated from a hundred years ago would have predicted, but now we found evidence for the fact that the vacuum has some energy density to it.

Marusek: Is that dark energy?

Loeb: Dark energy or cosmological constant. Now why is that related to the anthropic argument? Because as it turns out, if you try to come up with a fundamental theory of where the vacuum energy comes from, there is no simple explanation. In fact, according to String Theory, which is the most popular fundamental attempt to resolve the unification of gravity with quantum mechanics, the vacuum can have different energy densities, different conditions, in different places. And then you ask the question, why do we have one value for the vacuum energy right here? And the answer they came up with is the anthropic argument, because in those other regions where, for example, the vacuum is much denser, the universe would be rather short-lived. It would basically accelerate very quickly, you would not make stars, and you would not make life as we know it. So we obviously exist in a region that allows us to exist and that's why we see around us this particular value, even though it's not fundamental in any way. It allows us to exist. So whenever you ask where would life exist—it would exist in those regions that allow it to exist. And that's anthropic reasoning.

Dick: But I would just point out that it's a misnomer—it should not be the anthropic principle, because anthropos implies human. The laws of the universe are not fine-tuned for humans, they're fine-tuned for life. So I think a better term would be the bio-centric principle—that the laws of the universe somehow have embedded in them the possibility of life, not humans. It's caught on now, so it's probably too late, but it's really bio-centric, not anthropic.

Marusek: But it goes into the culture, I believe, where other types of fundamentalists—Christians—see the anthropic principle as a source of intelligent design, that all of these factors, all of these numbers that you could measure for our universe are tweaked in just such a way that we are here. In that sense, that's anthropic.

Dick: But there's a way to get around that and that is that there are many universes out there, a multiverse. We just happen to be in one where there is life. Of course, the problem is that you can't see those other universes. Martin Reece has written a whole book on multiverses. So it's a serious idea, but it's not provable yet.

Fischer: But, still, it's been tweaked for all of the other nearby stars and their planetary systems, as well.

Ferris: Okay. Maybe we should get to another topic. In terms of the question of why some people feel they've seen evidence for extraterrestrial life, what do you think is the driving force? Is it the one you mentioned of wanting knowledge that an extraterrestrial might come to the Earth? I could see a very logical argument to say we don't want any extraterrestrials here. It's going to just ruin our whole society. The usual example is when the Europeans came to North America and they were really decimated to a certain extent by disease and guns and a variety of things like this.

Loeb: Well, it's the fear of the unknown, in a way.

Ferris: Those are examples; it's not exactly the same.

Loeb: But the one advantage, of course, is that if they are much more advanced than we are. Instead of investing government money and answering questions, we can simply ask them: why is there a cosmological constant? We can save money and effort.

Fischer: I think there's an economic driver for finding extraterrestrial life, but the idea that they would travel across these great distances is, to me, hard to swallow. It would be much easier to communicate with them and we could still do that without having them come here.

Ferris: But what language are we using to communicate?

Fischer: Mathematics, some binary code we develop. I don't know. But if you do accept the idea that carbon-based life is likely, then, at least on Earth, carbon-based life has lifetimes of let's say a hundred years. It's rare to go much longer. And to get to the nearest star—I mean, if you really think about what it would take to travel to Alpha Centauri, the nearest star, just four light years away, you can accelerate a probe—let's make it a nanoprobe—to ten percent the speed of light, so it gets there in forty years and radios back the signal in four years. And about every ten years someone from NASA headquarters goes to the people at JPL and says, "What would it take to do this?" And everyone does the math and then they groan because there's no engine—no fission engines, no fusion engines, no propellant engines, no solar cells—that could do that at ten percent of the speed of light. So you have to go to something exotic—anti-matter engines—that might do it.

Dick: Yes, but if you're a post-biological extraterrestrial and you're immortal, you don't care how long—

Fischer: Right, it doesn't matter. And I think we might be looking for the wrong thing. I think you've hit exactly on the right point that instead of looking for life, maybe we should be looking for a little nanoprobe seeding the surfaces. You know, people say we did an experiment and looked at the moon and we've got square meter resolution of the surface of the moon and we don't see any spacecraft—they didn't leave behind any picnic lunches when they were here. But they wouldn't have sent that because energetically it's just infeasible.

Loeb: But there is the more fundamental question that Enrico Ferme, a very famous physicist, asked more than fifty years ago, which is if they are out there and they are quite ubiquitous, why haven't they visited us? Why haven't we seen them? And if we do archaeological digs, if we look down in the Earth, we don't find evidence of high technology. We don't find monitors or palm pilots or things like that in archaeological digs. And why is that? Maybe they're not out there.

Itzkoff: But we always sort of take it for granted that alien life is either going to be benevolent and give us all the technology and answers to the questions we want or it will be belligerent and come to conquer us. But what if it's indifferent—what if it figured us out a billion years ago and didn't think we were that interesting and just kind of moved on.

Dick: I think the Ferme Paradox is a serious argument, but there are many ways around it. There's a book, *Fifty Ways to Get around the Ferme Paradox*. One of them is that they don't like to travel or they've been here already and went away because we weren't interesting. Or there's the zoo hypothesis, where they're at the edge of the solar system waiting for us to get our act together. So it does have to be taken seriously and it's stimulated a lot of thought, but it's not a showstopper. Although I have to say that this did play into the reason that Congress cut the money because this argument was prevalent back in the early 1990s. Frank Tippler is the one who made it very strongly. And the Congressman in 1993 who cut the SETI program said that if they've proven with the Ferme Paradox that they don't exist, why are we wasting money?

Fischer: Right, but it's a very slim slice of parameter space that's been excluded. But, you're right, you do have to say something's been excluded. There aren't Klingons buzzing around, but, as Avi said, there's the narrow range of frequencies that SETI has scanned at. So if you think about all of the parameter space where you might detect something, what we've excluded so far is tiny.

Loeb: The thing is that most people don't care. We don't have searches like SETI that are covering the large range of parameter space. And we don't put much of our resources in that direction. So it's not only that they are not invested in that, but we aren't either. We prefer to remain ignorant, I guess.

Dick: Coming back to what you said earlier when you talked about the societal impact of extraterrestrial intelligence, there have been readings on this and one of the things everybody agrees on is that there's no consensus on what the impact will be and you certainly can't predict it. It is very scenario-dependent. It depends on, for example, whether the contact is remote or near. If you have a UFO land at the White House, that's one impact; if you get a signal from a star a hundred light years away, that's another impact. The historical analogs like the culture contacts on the Earth—you can pick your horror story: the Aztecs or the Incas or whatever—are not very pretty. But that's not what's likely to happen, unless it's a UFO scenario. It's more likely to be a remote contact and there you have historical analogs, too, especially if you have information transmission. For example, the knowledge of the ancient Greeks was passed on to the Latin West by the Arabs, which resulted in a renaissance. And that's an interesting one to pick apart because it was a dead civilization whose information was transmitted to another civilization and stimulated it.

Loeb: The other thing that one has to keep in mind is that the sun will not last forever. It's now in the middle of its life and it'll last another five billion years. After that we will have to find another place. And knowing that there are places where we can go might be useful. The sun is just a furnace that is keeping us warm and we just happen to be here, but it might not be the ideal place in the long run.

Fischer: But we lose water in another billion years. We're losing water right now and in another billion years, we will lose all the water on the surface of the Earth, unless it's being replenished. So we have less than five billion years.

Dick: You still shouldn't lose any sleep over it. If you said a million, then you would lose sleep.

Fischer: The other thing is that we look at our solar system and we have this view that we have one habitable planet, but there's no reason that, for example, Mars and Venus couldn't have formed in each other's place. If they had, we would very likely have two habitable planets in our solar system and we'd have a very different view, I think, of the possibilities of life and we'd have a planet to hop to as our sun is evolving and becoming more luminous and it's becoming hotter here.

Dick: Speaking of solar systems, I wonder if Debra wants to say something about the other ones that we've found because that's one of the things you do.

Fischer: The most interesting characteristic of the other solar systems is that when we started finding multiple planet systems and started analyzing the dynamics and the interactions of the planets, I learned for the first time that our solar system with nine planets—or now eight—sits actually on the verge of stability. It's slightly chaotic and Jack Wisdom and Jacques Laskar showed that in the late 1980s. But given enough time, I think Mercury is the first planet to go. It has some eccentricity. And Pluto—which is no longer a planet, anyway, so we don't care—is the next one to go. And then the planets relax into filling that gravitational space, but right now, the planets are all pushed up against one another. Gravitationally, they each have their gravitational domain and those domains are pressed up against each other. And we see that same characteristic in other solar systems, which is what makes me think that it's likely that there are other stars that have not just one Earth, but two Earths.

Dick: But we haven't found any Earths yet.

Fischer: We've found six Earth mass planets and we are certainly working very hard in that direction.

Dick: Does that include the several that are around the pulsars—the neutron stars?

Fischer: No, I'm sorry, we've found those as well, but those are formed by a completely different means.

Loeb: But they're not at the right distance to the Earths.

Fischer: Yes.

Loeb: So you wouldn't expect that there would be water there.

Fischer: Well, it depends on the type of star and what we're working on in terms of our science is to find Earths. We're working with Greg Laughlin right now. We have a proposed project where we think we can find not just Earth, but Venus, Earth, Mars, and maybe even Mercury around the two Alpha Centauri stars—if they exist there.

Dick: But the vast majority have been these gas giants like Pluto or bigger.

Fischer: I would say in the first seven years that was true and now we've found all of those and the planets that we're finding now as our precision improves are all more like Saturns and Neptunes.

Dick: And of course the Kepler spacecraft is going up next year and we'll find even the smaller ones.

Fischer: Yes, in 2008. That's right. And it should find out at least what the frequency of rocky planets is.

Itzkoff: How do you decide even which direction to go looking in? You basically have 360 degrees to look out into.

Fischer: We look at all 360 degrees.

Itzkoff: All at once?

Fischer: Yes, we have surveys—at least for our projects—from Keck and Magellan, and Chile, and AAAT, and of course there's a Swiss team. So we're looking at every star that we can that's bright enough and chromospherically quiet enough.

Marusek: How close is the closest star system that you've found?

Fischer: Fifteen light years away.

Marusek: What's it called?

Fischer: Gliese 876.

Ferris: But in most of the ones that you find you're able to detect Earth-like ones now? Or you can only detect giant ones.

Fischer: Around the low-mass stars, two things happen: first of all, low-mass stars are the most populous, the most common stars in our universe by far.

Ferris: Low-mass meaning…?

Fischer: Meaning half the mass of the sun or a third of the mass of the sun. Those are the stars that are everywhere; they comprise seventy percent of the stars in our galaxy.

Loeb: And they're also longer-lived.

Fischer: They live forever and, because they're lower mass, they're less luminous and so that means the habitable zone that we talked about before, where liquid water can survive, moves in. So now you've got a low-mass star and the tug of the planet on the star—the reflex velocity—is greater. Because it's closer, the reflex velocity is greater and the period is shorter. And so it's very possible around M dwarfs that we'll find Earth-like planets in the habitable zones.

Ferris: Can you just say briefly what this procedure is? I don't think a lot of people here know how you do this.

Fischer: We don't actually see the planet. We know we can't see the planets—the scattered light from the star, even above the Earth's atmosphere, is so great it would obliterate any reflected light from the planet. We know that the planet exerts a gravitational effect on the star. A star, of course, hangs on gravitationally to the planet and that's what keeps it in an orbit, but as the planet is orbiting the star, it actually orbits a common center of mass and it tugs this star around this common center of mass. And so we're looking at this bright object—the star—which is wobbling, and then we mathematically model that wobble with the mass of the unseen planet. Now, we haven't seen the planets, so we're using physics to find the planets. And when the planet goes across the face of the star, the starlight dims. And we can say at exactly what minute the starlight should begin to dim and that's what we did in 1999 and found the first planet transiting across the face of the star. Now we follow up and we can see not just the dimming of the starlight, but we can see constituents in the atmosphere of the planet with the Hubble space telescope.

Dick: And that's what Kepler is going to do, too.

Fischer: To look at transits, right.

Dick: Can you come back to the Drake Equation for just a minute? Can you put a number on that parameter in the Drake Equation now with the fraction of stars that have planetary systems?

Fischer: I think it's hard for a star to form without planets. The star has to get rid of the planets somehow. We're finding giant gas planets around something like fifteen percent of the stars. Would we see Jupiter? We're actually on the verge of being able to say yes, we can see Jupiter and we see lots of systems that look like they're going to be analogs of our system with a Jupiter that's far out. But it'll still be hard to detect our solar system and all we would have seen so far is Jupiter, perhaps. And the gas giant planets it turns out are a little more demanding to form. They certainly form faster, but they probably require higher chemical composition in the proto-planetary disk to form, so that they form fast enough to grab onto the gas atmosphere while it's still there. Rocks like our Earth—certainly rocks like Mars and the moon—I imagine form all the time. And now you need some mechanism to actually collide those bodies, these moon-size objects, to build up to the size of the Earth. So that's the challenge.

Dick: So we have some idea of the first two elements of the Drake Equation. The first one is the rate of star formation and the second one is the number of planets. But the next one is—

Fischer: The fraction that have life.

Dick: The fraction that have conditions for life. And I think we don't know that at all.

Fischer: Right, but that one, again, I would bet is easy. I think it's the next one that I have trouble with: the fraction that actually forms life.

Ferris: Well, maybe we should let other people ask questions.

Marusek: Dr. Ferris, before we do, I'd like to suggest that whether or not there is extraterrestrial life and intelligent life out there, it's still an important part of our culture and has been for a little over 100 years. And that's kind of my bailiwick, to think about what ETs mean to us. And, if you don't mind, I'd like to give a little thumbnail sketch of the last 100 years.

To start, I'd say that as a genre science fiction was only possible when people were able to see the fruits of science in their daily lives—in other words, technology. I'm thinking of the steam engine, electricity, flight. Therefore, science fiction as a genre really only started with the Industrial Revolution.

Today, with changes happening every five minutes, you can say we live in a science fiction world. Although there is historical background for aliens that goes back thousands of years, the modern alien is a product of Darwin because, before then, at least in the West—and I'm really just talking about in the West—those other planets that we were able to see were thought to have life. But because we are created in God's image, we would assume that they were, too, and that the aliens—the populations of the other planets—before Darwin were seen as somehow humanoid. Maybe a little bit different—they might have different colored skin, they might have wings. And that is from our age of exploration when the West and Europe were starting to see other peoples.

After Darwin, however, the idea started to proliferate that the biological unit, the creature or organism, is adapted to its ecological niche. And we were also observing planets better to see that they had different conditions. Therefore, any creature that would live on these planets would have to conform to their local environment and maybe not even be human. And so there is the modern idea of the alien. And I think there were some French writers who first took it up within ten years of the release of *Origin of the Species* in 1859. In English, the granddaddy of alien science fiction has to be H.G. Wells, and he put out his book *War of the Worlds* in 1898. H.G. Wells invented the malicious alien invader from Mars. He also invented the time machine, the invisible man—a lot of our tropes come from him.

The concept of aliens means "other," means "something not us," and aliens can be a lot of things, but this first trope, this first strong one that H.G. Wells came up with, was aliens as menacing, genocidal invaders. And when you think about when he wrote this, we were at the height of the British Empire—he was British—and they had just gone through the Boer War and imperialism was entering a particularly nasty phase. And what he did was he flipped it around and he said, instead of us going out to conquer them, what happens if they conquer us? And his story—the *War of the Worlds* story—was of Mars, a highly technological planet, that was having its resources depleted and they looked across space and they saw this blue-green gem of Earth and they said, "We want that," and they came to get it. So, alien invasion—the idea of having a top predator. If we're biological creatures, there's going to be a top predator, and we're the top predator here, they're the top predator there, and whenever we meet, you can't have two organisms in the same niche, right? There's got to be one that wins and one that loses and that's one of the reasons why we may not want to be visible outside of our solar system.

Dick: And the opposite paradigm to that is *E.T.*, the nice alien.

Marusek: Yes, but that came 70 years after this. And this theme of the menacing invader has populated science fiction stories all the way up to today. This idea of the invasion—his story came back and hit us in the U.S. in 1938 with Orson Welles's radio play, *War of the Worlds*. That made such repercussions that we still talk about it today. Think about that. Now, that same movie has been redone and redone—it was just redone last year with Tom Cruise, right? And what was the invasion—what was the whole point of that movie? It seemed to me the point was how a divorced dad raises his daughter—it had so little to do with Martians, really. Think of other invasions—the 1950s were really rich with invasion ideas. In 1956, the movie *Invasion of the Body Snatchers* came out and my dad took me to see that—I was five years old—and he probably affected my life, getting me into science fiction. If you don't know this, it's a movie about this small town in America where, suddenly, people that you know, that you're related to—your grocer, your librarian—everybody is different. But they're completely the same as they were yesterday—they say the same things, they do the same things, everything is the same except their different. And they're spreading. And eventually they find pods where the people were being reproduced and when they were being reproduced, the real person, their original, would be eliminated.

Levy: That's a George Romero movie, isn't it?

Marusek: The director?

Itzkoff: No, he was *Night of the Living Dead*.

Marusek: Okay. Well, the point of that movie is being invaded by an alien species that you couldn't even tell from your neighbor—what did that mean? Well, probably it meant it was the fear of communism. The communists, you know, the fellow travelers—they're everywhere. McCarthy proved it. They were everywhere. And that's another interesting thing because this movie is being remade and will be released this August with Nicole Kidman and Daniel Craig.

Fischer: I want to see it.

Marusek: It'll be interesting to see in 2007 why we should be afraid of either being invaded or invading or how this takes shape. Even though this is probably the most popular and the most enduring trope of the aliens—it's not the only one. Right after that, in the 1910s, '20s and '30s, in the United States we would have writers like Edgar Rice Burroughs, who did the *Tarzan* series, but he also had his Martians and his Venusians and such. They were kind of boy's own adventure stories. Of course, in the '20s and the '30s there was the birth and the flowering of pulp fiction, with Hugo Gernsback's *Amazing Stories* and *Astounding Stories* and *Science Stories*, and all of these stories. And these books were pretty much just written for teenage boys and they didn't really have a large cultural impact. But the writers were exploring other things, other meanings for aliens. They explored what if *we* are the aliens. They explored what if *God* is an alien. What if aliens are female vampires? They explored a lot of things other than just plain old invasion.

But then we come into the '40s—well, 1938 was an interesting year because not only was there the radio play *War of the Worlds*, but 1938 was the introduction of the first paperbacks in the United States and we're going right into war, and science fiction just went right into the paperbacks. It went from pulp magazines into paperbacks. The science fiction writers who came back from the war were not that much interested in invasion and such; it started falling out of favor with writers. They were starting to become more mature in their themes. After the war, first contact was an important theme. And you can kind of see why because so many Americans, including science fiction writers, were making first contact with the world at that time. And there was the idea that first contact had to be friendly and measured and well thought out, and not just two opposing forces meeting in the dark of space. Even though this was dying out in written science fiction—the idea of the space invaders—that's when Hollywood grabbed it and ran with it and that's when we had all of the bug-eyed monster movies. How do you tell if an alien is a good alien or a bad alien? An evil alien either has tentacles, is insectoid or reptilian; a good alien is mammalian, maybe even humanoid, or avian, which is kind of interesting. Well, the movies perhaps have more of a pulse on what the population is afraid of. Movies are never very adventuresome; they don't get beyond the menacing invasion. On the other hand, the written science fiction wasn't really being read by the general public yet. That really didn't start happening until later.

In the '40s and '50s, aliens were explored as a mirror, you might say. You could hold up this alien and see yourself. And we could explore a lot of things, even a lot of controversial things, more easily. If you write about race relations or gender relations or whatever, a lot of people will get their hackles up right away, but if you're writing about aliens, then you can kind of make your point and have it read and thought about and not be turned off right away. So in the late '40s and '50s, aliens were used to explore human society—sexuality, race, militarism, colonialism, vanity, prejudice. And religious transcendence became very important and very popular.

That brings us up to today. Ever since you guys invited me, I was trying to research this and I even interviewed a couple of very influential science fiction editors to find out what aliens are today. Because we've lived with aliens now for 100 years and we've experimented with using them as foils and mirrors, but what are they today? Here's the answer I came up with—it was actually in last Sunday's paper. This is a Ziggy cartoon. There's a spaceship coming down to see Ziggy and the caption is—the alien is speaking—"Ah, nuts! Well, what states don't have residency requirements for welfare?" So today it would seem that what aliens mean are undocumented aliens. Aliens are not a harbinger of bug-eyed monsters, but the harbingers of globalization for all levels of society and power. If you think of the *Men in Black* movies, aliens work at the post office, aliens work at convenience stores, aliens are everywhere. They move into the neighborhood, there may be a little bit of friction, but they blend in, they melt in the melting pot, and we accept them. Then you go to a movie like the last series of the *Star Wars* movies and think of a scene around this Jedi counsel—remember that scene with the Jedi counsel and there were all those funny aliens—well, there's globalism. The aliens are our equals—at least, we're in the same room with them and we're discussing issues of intergalactic import.

Levy: What you've been coming up to is a very pregnant area and it seems to me that why we invited you was that science fiction represents the imagination. The last point you come to is that the manifestation of characterizations of aliens in science fiction is an allegory or a projection of the problems that we have on Earth, but I think coming back to your point about post-biologic man you can look at Steven Spielberg's *A.I.* The movie was not very well received and I believe that the reason why the movie was not very well received is that in fact the science fiction of the movie contains a very interesting possibility. When we started the talk today, this notion of life, biological life, seemed incredibly limited to me, and the notion that algorithms, computer algorithms, could replicate and go on without the materialized body is very upsetting in the movie. I think people are rejecting this movie. But I think that the movie contains the germs of another way to understand this search for life. That life can continue on in a non-organic form, that life can start to develop within the consciousnesses of computers. I think that was what the movie was saying. I like the whole history of what the science fiction world has contributed because science itself is limited by the scientific process.

Marusek: Exactly. And these two editors that I mentioned—David Hartwell and Gordon Van Gelder—I asked them for the four leading themes of the science fiction stories they see coming across their desk today. And aliens are not in that top three or four. But this very issue of the post-human, of what we're going to become, is one of the top themes. That's what we're really writing about these days. Not aliens, per se. In science fiction, think of *Battlestar Gallactica*—I don't know if you've all seen that. Those aren't aliens that are coming to invade us. It's another invasion story, but those aren't aliens, those are cyborgs. Those are machines—toasters.

Audience: And they're the products of human creation.

Marusek: Right. They're our own children.

Loeb: There is also the possibility that biology will allow us to understand better why we die after one hundred years or fifty years or some number of years. We could lengthen that. We could, in principle, lengthen it to a million years and then people will die not because of biology, but because of accidents and things like that.

Itzkoff: It does seem that in the science fiction that I've been reading just in the last five or ten years that there's been a decline in the interest of the purely biological alien and I wonder if that's a function of the larger populous, because they don't feel like they're seeing results in the science and they're losing a little bit of interest in that kind of science and are being steered toward science where they do feel like they're seeing results or they feel like it has some more immediate impact. That's part of the reason why maybe the government is not as eager to fund these projects. People in the public need to be stimulated again and they feel like they need to see more immediate results or results that can be made tangible to them in some way or give them some kind of hope or something to imagine. That will make them interested in these kinds of aliens again.

Dick: On the other hand, I think you're right that machines have a bad rap. People don't want to think of themselves as turning into machines.

Loeb: But the reason this is happening now is probably because of the internet, the fact that knowledge or information is starting to get center stage. The Communists back in the '50s triggered another version of aliens; the Internet age is triggering yet another version. So, again, it's just a mirror we're holding.

Nersessian: It seems to me that what you were saying is that what makes people anxious creates an imagination of something that's going to diminish their anxiety. So if we are afraid of the Communists, then we create a whole set of stories, which is what children do. The way children overcome their anxieties is by creating play, and through the play they work out their anxiety. If that were the case, then you would ask what is the reason for this search for extraterrestrial life. Is it also based on some kind of anxiety? And what would that anxiety be? Is it possibly connected to fear of death and issues of immortality, that we could find something in other places that give you another opportunity to be somewhere else?

Loeb: But there is value to knowledge for the sake of knowledge, just knowing whether we are unique, the only intelligent organisms out there, or not. In some sense, science is sort of childish because we just want to know, we just want to figure out answers to questions rather than speculating about it. The fiction is about speculating, it's about imagining things, and usually you imagine things based on what you see around you, things that look peculiar or strange. So people imagine things, but science is about getting answers. It's a real thing. So suppose someone is very anxious about their ability to find a mate, say a man is looking for a woman and he can invent stories about it or he can go out and find someone. And that's what science is about—going out and finding something.

Dick: But I think there are many reasons. That may be one reason, and yet another reason is to look for a place in the universe. I don't think you have to say there's just one reason. Different people have different reasons.

Itzkoff: And it can also be motivated by just not wanting to be lonely.

Ferris: Let's let some other people ask questions.

Audience: As he said, it's more than one reason. *War of the Worlds* was written, and then in 1939, British imperialism was endangered and they became less than what they were when Wells wrote that. Or 1938 with Orson Welles—World War II was coming, so all those things are happening. And then the scientists—well, science is a lot better for people in the sense that it can enable us to live longer or something like that. An artist like Welles, in my opinion, wasn't that great in terms of his politics, but he was a good artist. So it depends on all these different things, but there are all these motivations behind it. And a lot has to do with what people want and what people need.

Audience: I was just going to follow up on what Ed said that a lot of science fiction tends to treat exaggerated conflicts. In all of these, whether it's the Body Snatchers or whatever, these are all primitive experiences that are being described. Seeing oneself inhabited by another or seeing our parents suddenly transformed and acting aggressively and they want to eat you or whatever—these are analogies of the sort of experiences that every infant goes through in its first two years of life. And I think there are very basic psychological motives at play in our desire to find something else in the universe, the way that even as newborns we look for others to find.

Levy: All the things that have come up are generated out of existential predicaments or developmental predicaments.

Audience: And they follow the logic that we know and have experienced.

Ferris: As moderator, I'll call on my daughter.

Allison Ferris: Well, I'm really interested in this whole notion of imagination—I'm an art historian, so I'm interested in art, and my dad is a scientist. My name is Allison Ferris. Imagination seems to be one of human's strongest talents and capabilities and in the 19th century, the disciplines were less separated. And there were often times when there would be roundtables like this and there would be ministers, scientists, historians—people talked about these big issues together all the time. And that isn't happening anymore. Instead, scientists—as much I respect you all and my dad—are, as you said, considered the people who have the truth, who can prove the truth in some way or another, whereas the wacky artists or science fiction writer, they're just way out there and don't contribute anything. But I'm wondering if as humans—

Marusek: Whoa.

Allison Ferris: No, I'm on your side. If there were more conversations in which more different kinds of people came together to use our imaginations, could we get farther, if there were more of these kinds of discussions? Perhaps as scientists, you have limited ways of thinking about what life could be or ways that it could happen and maybe discussions like this could really kind of contribute to that. And I'm just wondering what you all would think about that kind of process.

Loeb: I completely agree with you. I think you're right. For example, Jules Verne came up with many ideas that we now see in daily life. It's quite possible that people who do not practice science have fewer boundaries in what they imagine and so they can come up with ideas, many of which are impractical, but every now and then, if one of them works, it can be a remarkable achievement.

Audience: My name is Andrew. I don't know how to phrase the question, but this conversation begs for this to be brought in: Scientology. This is a religion that's based on aliens and the idea of aliens invading Earth and here we have in the 21st century people believing this and doing well by it, frankly. So it's a combination of science and science fiction and aliens and religion coming to play here.

Dick: I'll comment on that. I think it's one way of—I think the biological universe is kind of a world view. I think UFOs and science fiction and that kind of thing—Scientology—those are ways of working out this worldview.

Marusek: And besides, wasn't that R.L. Hubbard?

Dick: He was a science fiction writer, yes.

Audience: I'm Michael Sacks. Somehow I see a connection between what we're talking about right now and earlier symposiums that we've had in the Center. And I'm talking about the brain/mind consciousness. And in a sense, when we're looking for life outside our solar system that we fear we see what our life is here. But when you get to the brain/mind consciousness, we are beginning to explore what consciousness is and what creates it and how it manifests itself. So it seems to me that when we talk about something like artificial intelligence, it raises the question of the possibility that we can have consciousness on a non-organic basis, that in a way it goes back to both something we know less about than we do about life. But in getting into it and answering it for ourselves, it raises this much larger issue of artificial intelligence and a post-biological era. It seems that you've got that direct tie-in between that and the exploration of consciousness that has been done in the past in this very room.

Dick: I think one of the great things about the extraterrestrial life debate is that it puts us in perspective. It's an entirely new perspective and makes you ask new questions and consciousness is one of them.

Audience: I have a question for Debra Fischer. You mentioned this ability to replicate moving one-tenth the speed of light. What is the possibility of us accelerating that? Is there something that we could do, because we always seem to use that as barometer—the speed of light? Is there anything possible that can move it faster? Because if you take the computer, everyday something comes out faster, you're able to move and transmit information faster. Can we use a different system? My second question is for the audience. Does this metamorphosis, like the caterpillar to the butterfly, exist in the scientific universe that we're talking about? Can something that's out there that we already know all of sudden just open up and change and become something else?

Fischer: Well, I'll start with the first one. I think there's probably a fundamental limit—we're stuck at the speed of light. But going just a fraction of the speed of light would make a huge difference. We could begin to think about traveling to nearby star systems.

Audience: My point also is you mention forty years going and forty years coming back—we're very impatient—the experiment would take 300 years. But, if it's 300 years, we could still invest that time.

Fischer: That's right, yes. And if you look 500 years ago, where we were in terms of energy and the amount of energy we could access—coal and oil have a made a huge difference, we've tapped into that as an energy-rich source and maybe in the next 500 years, they'll be something else—fusion in particular comes to mind and anti-matter engines. If we go about really harvesting enough, we can collect anti-matter at linear accelerators and store it in magnetic bottles and then use it as a tremendous energy source to move things. I don't know if that answers your question, though. I think you're thinking about worm holes or something.

Loeb: That's what I was about to mention. The thing is the speed of light is a fundamental constant, according to Einstein's theory of relativity, and you cannot exceed that with any material object. But space and time as a whole could have some complicated geometry that allows you to visit another point instantaneously, in principle. For example, imagine that space was finite and then you wrap it around and connect it back and then you can get from points that originally were apart instantaneously. And people have dreamed about solutions like that. They call them worm holes. In the context of the general theory of relativity, all the studies show that you cannot really go through objects. A macroscopic object like us cannot really go through a worm hole and appear somewhere else, fifty light years away, instantaneously, because they close up very quickly. If you try to solve the equations, you can't really go through them. But, in principle, it's a possibility that someone will come up with a machine that allows you to visit another place.

Audience: Didn't the *Dune* chronicles talk about folding space also, like an accordion?

Loeb: Yes. In fact, in the movie *Contact*, I think they borrowed this idea of worm holes.

Audience: I just wanted to see what the panelists thought of the long-shot idea that's circulating around that the place to look for extraterrestrial life is actually here on Earth, that maybe there is microbial extraterrestrial life that has been sitting quietly, unnoticed, in the deep biosphere or other places. And for just the same reason that we didn't detect the deep biosphere until we really thought to go look at it, maybe there are these alien micro-organisms, which we're not picking up on DNA assays and so on, because they use a slightly different metabolism, but that they are living among us, just like all the best aliens from science fiction. And that maybe the search should start screening for these kinds of alien organisms and what you thought of that attempt.

Fischer: My first guess is that if they're here—and you're right, we would miss them because the tests that we use are very specific to the things that we're looking for—that it's more likely that they sprung up here as a separate life form. Just traveling the immense distances between stars, the exchange rate from one star to another, even with rogue planets that are ejected from solar systems, as they certainly are, the cross-section for hitting another and being captured by another planetary system is difficult.

Dick: Directed transpermia. I wouldn't totally dismiss the idea but I think the point is to be able to prove it. We do know that there's material that goes between and among the planets now. Who would've thought that we'd find these dozens of rocks from Mars—you know, the ALH84001 from 1996. We don't think now that there are actual nano fossils and when you think about it, it would have been strikingly surprising if a few of the rocks that had landed on the Earth from Mars were the ones that had fossils in them. They may be up there, but there is an exchange of material among the planets.

Audience: What was that word you used?

Dick: Directed panspermia. The idea of directed panspermia is that the extraterrestrials out there send out these seeds.

Audience: I'm interested in what made you interested in this topic in the first place from your disciplines and also, despite being an unprejudiced scientist, would you lay money on there being extraterrestrial life and what form would you imagine it to be?

Fischer: I'll put down $100 bucks that there's something there.

Ferris: I would vote for that, too, for very simple life forms, exceedingly primitive.

Fischer: To me, it feels like before 1995, no planets had been found before and we all said well, they must be there, we just can't see them. We put together the puzzle pieces and the theory of planet formation and everything was sort of pointing in that direction and I feel we're in a similar position today. It's hard to detect but it just seems so unlikely to me that there's not something out there. What form is it in? Well, microbial is going to be the easiest and anything more advanced is going to be harder, but there are still a lot of rolls of the dice.

Loeb: One way to see how ubiquitous life is is to look at the early Earth and what people find is that as soon as the Earth cooled and allowed life to exist in the sense of chemical reactions that would produce organic molecules, life started. So it's generic. Whenever the conditions arrive, it will fall. And that makes many scientists believe that it's quite likely that it's out there. Whether intelligent life develops out of it is a different question.

Ferris: How much are you going to put down on it?

Loeb: My house.

Dick: I'll see your house. I'll just say how I got interested in this and then unfortunately I have to go right away. I was very much influenced in 1966 by the Shklovskii and Sagan book—a famous book known as the "bible of SETI," by the Russian astronomer Shklovskii and Carl Sagan, *Intelligent Life in the Universe*. At that point, I was getting my degree in astrophysics, but I was always interested in how we came to these ideas. So I went into a Ph.D. program in the history of science and decided to do a dissertation on the history of the debate and looking around, I thought I would find some books on it, but there weren't any books on it because it was a taboo subject back then and to some extent, still is. I was in the History of Science department and when I proposed it for dissertation, I was told, "There are two problems with that: first of all, it's not science, and secondly, it has no history." Well, I'm still talking about the history and there have been many books written on the history now. So that's how I got into it.

Audience: The issue was raised about whether SETI and the search for extraterrestrial life is a religious issue or not. One of the things that I think distinguishes science from religion is that there's a way not only to prove the positive but to prove the negative. And it seems in this case that people who are looking will always say, "Well, we'll have to look some place else." And there's no way they'll ever give up.

Loeb: Well, that's true of other disciplines in science where the search is going on and nothing is found. It's quite a legitimate result.

Audience: But lots of times there's a way of proving the negative.

Loeb: That's true.

Audience: Just a fast question to Dr. Loeb—early in the discussion you said something about the fact that our uniqueness is just chemical and if we would understand that we would understand something of its ever-presence. Could you clarify that and also, when you talk about chemical, does that make it biological? Then we could distinguish between the science fiction fears that we have now—talking about the Ray Kurzweil method, that it's not biological. It then becomes mechanical and has a mechanical life of itself. I'm asking for your clarity on the chemistry question first.

Loeb: The idea of the chemistry is that you start with very simple atoms or molecules that we find to be ubiquitous in the universe, especially in our galaxy that was enriched by heavy elements from stars exploding. Then you take these building blocks and you put them in a solvent like water and chemical reactions take place. There are sparks due to discharges. And then you start making more complicated molecules out of that. In fact, there was a famous experiment done more than fifty years ago, and the idea was that you start building up more complex molecules and it's just a matter of the chemistry eventually ending up in things that look like RNA. And the RNA is able to produce DNA, although major parts of this sequence of getting to biology are not yet understood. So people are trying to do laboratory experiments under different conditions. It's a field that is starting to be experimental now, in the laboratory, trying to reproduce conditions that would allow you to develop complex biology.

Ferris: Yes, you hope you find a certain set of conditions. It's been difficult, let's put it that way.

Audience: If you take some kind of living organism and put it on the moon, what will happen?

Loeb: It will die because there is no atmosphere so there is no way for it to breathe. But moreover, it turns out that astronauts were very lucky because whenever there was an astronaut on the moon, there was never a storm on the surface of the sun. The sun has these storms every now and then and you can be killed by those storms because they are high in x-rays and when they impact a living organism, they basically kill it. What protects us here on Earth is the atmosphere that blocks the UV radiation and soft x-rays. On the moon, you're not protected. So one of the questions that NASA is addressing now is they want to have colonies on the moon doing various things and the issue is how to protect people and how to allow them to survive for long periods of time.

Marusek: I'll take the second part of his question—non-biological life. I believe you're talking about artificial intelligence, right? This is what in fact science fiction writers today are most concerned about—well, not most, but we're really turning it over—and it's kind of a quandary. You can't write about the distant future, say 200 years and beyond, without running into something that's called "singularity." And what science fiction writers today mean by singularity is that if and when we do create artificial intelligence, the same law of exponential growth will apply to them as it has to, say, computers and other technology, where every six months it doubles in capacity or speed or such. And this artificial intelligence will be self-directed. They will be teaching themselves to teach themselves and growing at such a rate that within a very short amount of time, they would be so far beyond us in intelligence that we'd be like a mouse looking up at a human. And then what happens?

Audience: You were talking earlier about all the efforts we're making to detect life, if it exists, by picking radio signals and also having the technology to detect life if it's like ours, to detect an Earth if it's fifty million light years away. What kind of signals are we sending out to be detected, if any? And if we are, what are we saying in those messages? And if not, what do you think we should say? And are we also making any of efforts to send out a message in a bottle—that is to say, "We are here," or "We were here."

Ferris: Our expert on SETI has just left. But he did say that we are sending out signals.

Loeb: We are not doing it routinely. There were several instances in the history that people have sent out things, but it's a high-priority item.

Fischer: Well, the first five minutes of Arecibo, that they transmitted instead of just receiving and got into a lot of trouble for that because the politicians said, "Wait, if you're in the middle of a jungle, you don't stand up and wave your hands." It's almost impossible to imagine they'll be picked up, but a true bottle that was sort of sent out into space is the Voyager spacecraft, which is now out beyond the heliopause and it's inscribed with a plate that has a figure of man and woman and it directs the alien beings to our location by neutron stars, pulsars that they might see, which show the location of the sun. And it has some basic binary code to tell them a little bit about life.

Audience: And it also had recordings on it, right? Blind Willie Johnson, the old bluesman, and Bach.

Fischer: That's right, it did.

Audience: What's the heliopause?

Fischer: It's the edge where the solar wind is going out and it's sort of the edge where it's now diminished so much that you can cross over.

Audience: So it's not routine to send out a signal but we assume that we're going to find some life form that is sending signals.

Fischer: I think that's an important point, yes.

Marusek: There's a bit of controversy about just that right now. A couple of issues ago in *Nature* magazine there was a letter about this. There's something called METI, which is "Messages to Extraterrestrial Intelligence," also called Active SETI, in which scientists are arguing that they should be doing just that—sending out messages. But, of course, the counter-argument is don't wave your hands until you know that you can handle it.

Audience: It's like find them before they find us.

Marusek: Yes.

Itzkoff: I was at the SETI Institute about three months ago and from what I understand, they don't do any active transmission. I mean they do a radio show, but that's just for Earthlings.

Marusek: If you want to read a terrific book to really make you afraid of sending messages out, read Greg Bear's *The Forge of God*. It's a few years old, but it's in the top ten of my all-time science fiction books that I read and boy. It scared the bejesus out of me.

Audience: When I read about android robots in the news now, most of the scientists doing the work on them seem to be from Japan and I was wondering what it is about Japanese culture that is particularly fascinated by androids and creating life that is similar to what we know. They make android dogs and android human maids and things like that.

Itzkoff: Well, they probably get a little more credit, but I think there's definitely a lot of cultural sharing between Japan and America. This is a plug for myself, but I have a review of a book this week and it's a Japanese author writing in the style of H.P. Lovecraft. They didn't name their android the "Asimo" just because it was a great name, but because it was a tribute to Isaac Asimov, so wherever they have got to, they owe the Americans some thanks for that, too.

Fischer: But they are ahead. We've fallen behind in nanotechnology and all sorts of things for reasons that are beyond the scope of this discussion. It's true that they've had a more dedicated effort. We think about this SETI search, if it's going to be active just looking for life. NASA is planning a whole Moon-Mars program and the reason is not scientific—it's to bring the solar system within our economic sphere and for defense reasons. So it sounds to me like we are going to go on, whether we like it or not.

Loeb: Well, the main reason is the Chinese.

Fischer: Yes, that's the discussion on the floor of the Senate. God forbid we go to the moon and there's a Chinese flag there. That's the level of discussion.

Itzkoff: I've heard people ask this question before and I'll mention it, too—once somebody's up on this planet or on the moon that's supposed to have an affiliation with the United States, how do we make sure that our form of government remains the same? Why don't they just form their own government and then become the Independent States of Mars.

Fischer: They'll have a hard time being independent for many thousands of years, I think. But I think it is the vision of Michael Griffin that we become a space-faring nation, a space-faring civilization.

Ferris: Well, we've had a great discussion here and have come a long way.

Marusek: Audience participation: how many people believe that it's possible that there's extraterrestrial intelligence in the universe? Okay, that's a lot. Next question: how many people believe that there in fact are extraterrestrial intelligent beings out there? Lots of surveys have been done, but I think thirty percent of Americans believe this. Now, the next question: how many of you have—not seen them, seeing them doesn't count—how many of you have actually met them?

Fischer: I got a letter from somebody who did.

Marusek: Well, I have been running into people who not only have met them, but have been abducted by them, and since nobody raised their hand to admit that they've met them, I don't think we're going to get any abductees here, either.

Transcript prepared by
RA Fisher Ink, LLC
+1 718-797-0939 / 800-842-0692
ra@rafisherink.com