10-2-1975

"The Search for Extra-Terrestrial Life"

Donald L. DeVincenzi

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Portland State University
October 2, 1975

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Transcribed by Kincaid Davis, April 10, 2020
Audited by Carolee Harrison, June 2020

CARL DITTMER: On behalf of Portland State University, the College of Science, the Auxiliary Academic Activities Committee, the Environmental Sciences Seminar Committee, and the Division of Continuing Education, I welcome you to this lecture. It is a privilege to be able to present a speaker who will talk on a subject so vital to us as the one tonight. I am Carl Dittmer, the dean of the College of Science, and I take pleasure in introducing to you Dr. Robert O'Brien, assistant professor of chemistry and environmental sciences of the College of Science, who will introduce our speaker. Dr. O'Brien is an expert in the field of atmospheric chemistry and he is the chairman of our Environmental Sciences Seminar Committee. Dr. O'Brien.

DR. ROBERT O'BRIEN: Well, it's in turn a pleasure for me to introduce our speaker tonight, Dr. Donald L. DeVincenzi. Dr. DeVincenzi is by training a biochemist, he received his Ph.D. in biochemistry from University of California at Davis in 1968. Since then he's been employed by the National Aeronautics and Space Administration, to us NASA, in a variety of capacities, and his current profession might be more appropriately termed a planetary biologist. He has served as a technical assistant to the director of life sciences. He's been involved with the planetary biology program office for NASA in Washington D.C., and for the last year he's been assistant chief of the planetary biology division at NASA's Ames Research Center down in California, south of San Francisco. His research interests involve the structure and functions of proteins, and of course nowadays planetary biology. He's been involved in a variety of projects incorporated into NASA's overall space program, many of which of course deal with search for various forms of life, early forms of life, which may be present on various planets, the most current of which of course is the Viking program, which is going to try at least to put a soft-landing rocket on Mars, hopefully on July 4th of 1976. Tonight's talk will then deal with some of the early forms of life hopefully as they might relate to early forms of life on this planet, and as they may exist on Mars and elsewhere in space today. Dr. DeVincenzi.

[applause]

DR. DONALD L. DEVINCENZI: It's indeed a pleasure for me to speak to you tonight on one of my favorite subjects, extraterrestrial life, and the search for it. This has always been a subject that's been intellectually fascinating to me, but obviously has acquired a more practical meaning since it's part of my everyday work. Some forty years ago, most scientists were very skeptical at the thought and about the notion of existence of life elsewhere. However, during the years since then there have been many significant discoveries in very diverse scientific disciplines, disciplines as diverse as radio astronomy and molecular biology, which are starting to lead us to be able to piece together how life originated on Earth and therefore extrapolate into the question of whether or not life could exist elsewhere, in our solar system or beyond. This, a new science, which is really a combination of various disciplines, is the science of exobiology. That is, the study of extraterrestrial life. And of course the interesting thing, the unusual thing about the science of exobiology, is that it has yet to prove that its subject matter does indeed exist.

Now, the rationale that I propose to follow during the next few minutes, is to review what we know about the origin of life on Earth. After all, our Earth life is the only model that we have, and as part of the scientific approach to the solution of problems, we generally resort to model systems, so our model system obviously is Earth life. I'd like to talk about its beginnings, and its evolution, and then extrapolate from that model into a discussion about the possibility of similar processes occurring elsewhere beyond the Earth. So the very first consideration I'd like to make is the question of evolution of planets. I think that the question of the origin of life and the evolution of life is really very intimately associated with the question of the origin of the solar system, the origin of our Earth, and ultimately with the origin of the universe itself. And what we're really talking about is not strictly chemical evolution or biological evolution, but a broader picture, one of cosmic evolution. Now, if I could have the lights, I'd like to put on the first slide.

This slide is a picture of a spiral galaxy, in the constellation Andromeda. And there's really nothing very unusual about it. Its size and shape and characteristics are very similar to most spiral galaxies, including our own Milky Way galaxy. Now, we believe that planets are formed as a common accompaniment to the formation of a star. Again, as recently as a very few years ago, people thought that planets were the rule, rather than the exception. Our current astronomical theories however lead us to believe that the opposite is true. In the formation of galaxies like this, on a large scale, and in the formation of solar systems like our own, on a smaller scale, we believe that the processes that occurred started initially in huge gas clouds, huge masses of rotating gas, and as they rotated they flattened out into disc shapes, as you see characteristically here in this kind of galaxy, and also in our solar system, and that ultimately, the central star would condense and cast off gas masses, which would then condense and cool to form the planets. This is one of the currently accepted theories for planetary formation. So there really doesn't appear to be anything particularly unusual about our own little corner of the universe. We feel that this is how our solar system was formed, and we know that our solar system is situated in a typical spiral galaxy, like the one that you see here; we know that our sun is a typical sun. It's representative of a huge number of stars, it's what we call a dwarf type G star, situated on the outskirts of what's a typical spiral galaxy. The point is, there doesn't appear to be anything particularly unusual about our own little corner of the universe.

We have only indirect evidence at this time that there may be planetary systems around other stars. This evidence comes from the observations of stars as they move through the universe with time. And by this I mean observations over many periods of years, decades, thirty or forty years. We can observe, in examining specific stars, that some of them show perturbations in their motion when measured against a fixed background. This perturbation can be explained by the orbiting around that star of a planet the size of the planet Jupiter. So, based on these indirect observations, and based on our theories about how stellar systems form, we believe now that planetary systems commonly accompany the formation of a star. And planetary systems are not really unique and special, but are very common throughout the universe.

Now, if planetary systems condense, as we believe, from these huge masses of gas, then one would guess that the initial chemical composition of a planet would reflect the chemical composition of the mass of gas from which it condensed. Now, we know that within our own universe the most abundant elements are hydrogen, carbon, nitrogen, and oxygen. These are the most abundant elements in the universe, aside from helium. They also happen to form, make up, 99 percent or better of the elements found in the human body and in all living things. Now if our planet, for example, condensed out of a gas mass that was composed of these elements, because of the very large excess of hydrogen, we would expect that the primitive atmosphere of the Earth would be composed of the reduced compounds of those elements. That is, water, methane, ammonia, and then again a large excess of hydrogen. So we believe then that the primitive atmosphere of the Earth was what we call a very reducing atmosphere. And it did not have free carbon, free nitrogen, free oxygen, but rather the reduced components: water, ammonia and methane. We also believe that of course when the Earth was formed, the environmental conditions were much more violent than they are now, that there were large amounts of ultraviolet light striking the surface, that there were electric discharge in the clouds surrounding the planet, the Earth was being bombarded by ionizing radiation from the Sun, and of course, that there existed volcanic activity which produced heat. Now, when, if you were to do a laboratory experiment, and this has been done now, many times, where you start out with a mixture of gasses, like we believe existed on the primitive Earth, and you subject those gasses to these kinds of energy sources, you get the synthesis of a wide variety of organic molecules that are common and, in fact, essential components of living systems today. Organic compounds like the amino acids, which are the monomer units of proteins, and like purines and pyrimidine bases, which are the monomer units of nucleic acids, which are the genetic material of the cell.

Okay so, this in effect then is the theory of chemical evolution. We talked about planetary evolution a few minutes ago, chemical evolution says that you can start with the components of a primitive atmosphere, and with the energy sources available, synthesize compounds that are essential components of living systems. They are not living in and of themselves, but they are essential components of living systems. Now, what kind of proof do we have for this theory, aside from the fact of being able to do it in the laboratory? Well, our proof comes from a number of sources. One is from meteorites. This is a fragment of the Murchison meteorite, which landed in Australia in 1969. Very careful analytical analysis of the meteorite indicates that it contains the very same kinds of amino acids that I talked about in the previous slide. Amino acids that are found in our bodies and in living systems today. Furthermore, these amino acids are present in a form that indicates that they were not synthesized biologically. They were not synthesized as a result of a life process somewhere else, nor were they contaminated with those amino acids when they landed on Earth. The compositions, the structures of those amino acids are very different from the amino acids as they exist in the human body, although the amino acids themselves are the same. So this says, then, that these amino acids that are present in the meteorites, which came from outer space someplace, were synthesized abiologically. So chemical evolution is going on in outer space. Not only can we duplicate it in the laboratory, it's going on in outer space itself.

A second line of evidence comes from simple radioastronomical observations of interstellar space. By studying the microwave spectrum with radio telescopes, we can identify conclusively spectral features that are characteristic of many of the molecules that are important in chemical evolution experiments. We can identify molecules like hydrogen cyanide, which played a key role in the early evolution of organic compounds. Molecules like methanol, acetaldehyde which is a very reactive compound which leads to some of these compounds that are found in the meteorites, and also as an important intermediate in some of our bodies' metabolisms. So these observations, that is, the observation of these molecules existing already in outer space, the confirmation of identifying these molecules in the meteorites, give us what we feel is very strong evidence for the fact that chemical evolution, as we can simulate it in the laboratory, is actually occurring elsewhere, in the universe.

Okay, so, the next question is, we've achieved, we can achieve the synthesis from very simple molecules, we can achieve the synthesis of more complex molecules of the kind found in the human body and in living things. The next question is: In the course of events, how did cells originate? Individual, primitive cells. Again, we're making some progress along those lines. You see here, structures, which are formed by non-biological processes, but which resemble bacterial cells in very great detail. These particular structures are called proteinoid microspheres. They are produced by heating amino acids, which are the basic building blocks of proteins, the same amino acids that are present in living systems, at high temperatures to polymerize them, to link them up together in long chains. Then, these mixtures are stored, for relatively long periods of time, days, weeks even, in very concentrated solutions, and when you examine the products under the microscope you see structures like this, that look like cells. And in fact when you examine them in very close detail, they have fine structure, that is very characteristic of living cells. For example, their membrane has two layers to it, just like many bacterial cells have. In some cases you can see internal structures. In other cases you see junctions between two cells, which indicate that there may be an interaction between one and the other. These cells are able to take in nutrients, or to take in chemicals, let's say, specifically, not just randomly but specifically, and also extrude them into the outside medium. These spheres swell and contract as the solutions in which they're stored exhibit changes in concentration. Many of these properties are fundamental properties of living cells. The point then is that by simple, abiotic, non-biological means, we can get all the way from the elements, the basic elements of the universe and the basic elements of life, from those elements through organic molecules, all the way to structures that resemble cells. They're not living, but they do resemble cells. Perhaps, the most intriguing aspect of this kind of a structure is that it could have provided, during the early course of the development of life on Earth, a micro environment in which chemical evolution could further proceed, and out of which could have arisen the first replicating cell.

I'd like the lights for just a few minutes, please. Okay so, then we get into the question, so we have touched on the question then, of biological evolution. So the critical question then is, how do we get from this structure of inorganic, abiotic molecules into a replicating cell? And the answer is not known. That's where we're at now, that's the critical question, and is of course the most difficult one to answer. Now, we think that we know fairly well when life originated on Earth. The Earth itself was formed some four and a half billion years ago, and our analysis of ancient rocks and sediments indicates that life arose on Earth around three billion years ago. That's important because what that says is that it took a relatively short time, one billion years, if you think that's a short time—it's short in terms of the history of the universe and the history of the Earth—a relatively short time to get to a complete replicating cell, the very first cell. But then it took another three billion years to get around to us, to get around to a highly differentiated and diversified species capable of intelligence and technology. So, just the sequence of events and the timing is curious in itself. Of course, from the time of the first replicating cell to the present, we do have very good knowledge based on the Darwinian theory of evolution about the occurrence of events. The critical gap is between structures like the one I've showed you, which are nonliving, and the very first living replicating cell.

Okay in summary, then, the theory of chemical evolution, as I mentioned at the outset, appears to be better related to an overall theory of cosmic evolution. It's certainly interwoven with the evolution of the Earth, which in turn is interwoven and dependent upon the evolution of the solar system, the galaxy, and the universe. So, our scope really is broadening in the last few years, and it seems that the question of… that we are part of a grand scheme, part of a cosmic scheme if you will.

Now, I indicated earlier that our feeling is that stars invariably, during the course of their formation, have planets associated with them, planets formed as an outgrowth of the evolution of a star. Now, there are tens of billions of galaxies like the one I showed you in the very first slide, that we can see in the presently accessible universe. By the same token, there are an equal number, tens of billions of stars, within each galaxy. So you can imagine the staggering number of total stars in the presently accessible universe. And, if you believe that the theory of stellar evolution indicates that planetary systems are a common formation, accompanying the formation of a star commonly, then the conclusion is inescapable that there must be a vast number of sites throughout the universe where life could originate and evolve.

So, the question really boils down to, not so much *is* there life out there, but where is it, and how do we search for it? And that's what I'd like to spend the next few minutes discussing.

Now, the search strategy is kind of interesting. We know that our own solar system is devoid of intelligent life, except for the Earth, and sometimes that's questionable.

[laughter]

So, we're not about to send spacecraft, or spend time and effort looking for intelligent life, here. However, by the same token, sort of the reverse case, we feel that intelligence and technology are the ultimate products of this long process of chemical evolution, and given the number of sites, and given our confidence in the theory of the origin of life, we feel that there must be intelligent life, even advanced civilizations elsewhere scattered throughout these vast numbers of stars and galaxies. So, if we're talking about looking for intelligent life, that's one thing, we're talking about looking for intelligent life outside of our solar system, and not by space probes. Space probes cannot be constructed to travel across these huge distances that we know to exist between stars. So, we're talking about, or we have to talk about, another way of detecting life, intelligent life, outside of our solar system. Within our own solar system, we believe that intelligent life does not exist except for here, but we do not believe that the solar system is necessarily, *a priori*, based on what we know, devoid of other forms of life. So, within our own solar system then, which is accessible by spacecraft, we're attempting, by space probes, to look for other forms of life, perhaps more primitive forms of life, or, at the minimum, the signatures of life. That is, life-related molecules of the kinds that I've talked about.

So in the first case, in the case of extraterrestrial intelligent life, we're talking about the problem of interstellar communication; in the case of looking for primitive life forms in our own solar system, we're talking about the Viking project, and projects like that, designed to search for life on likely planetary targets within our own solar system. So I'd like to spend the rest of the time now talking about each of these two concepts… well, the concept of interstellar communication, because remember it is only a concept at this point, and secondly, Project Viking, which is a reality. I'd like to cover both of these subjects.

Now, with regard to interstellar communications, you may recall that in 1960, Dr. Frank Drake, a very prominent radio astronomer, conducted one of the very first searches of the universe for signals from extraterrestrial intelligent civilizations. This was done with the radio telescope at Arecibo in Puerto Rico. He listened for a number of weeks to signals from two specific target stars, and did not detect anything unusual. What you're looking for is a signal that is not random. A signal that has some sort of periodicity to it, some sort of a meaning to it. Now, since that time there have been numerous other studies conducted here in the United States, as well as in the Soviet Union, whose objective was the same, and all have failed. This is not surprising, of course, for a number of reasons. Number one: the vastness of space, that is, the great distances involved, number two: the sensitivities of receivers that you need to detect signals over these vast distances, number three: the tremendous number of target stars that you could look at, and on and on and on. However, in recent years, in the last couple of years, a new project is being conceived of. Not carried out, but conceived of, it's called Project Cyclops. And again the objective is the same, the objective of Project Cyclops is to search the universe for signals, intelligently contrived signals, that may signal a presence, or the existence, of extraterrestrial intelligence. Project Cyclops attempts to solve some of the problems inherent from the earlier studies. The main one being, the construction of a telescope or telescope system that can be effective out to these very great distances that we're talking about, and that can be adaptable and sensitive enough to pick up very weak signals. If I could have the lights again, I'd like to show you an artist's concept of what such a system might look like.

See, the idea is that even with the largest radio telescopes on Earth, they possess nowhere near the efficiency that would be needed to detect the expected weak signals from the distances involved. So, your alternatives are really two. Number one: you construct an absolutely huge telescope, and we just can't do that, physically, we don't have the technology to construct a telescope as large as would be needed to carry out this kind of a task. The second alternative is to hook a bunch of existing telescopes together, to make them act as one. That is to construct a very large array composed of individual radio telescopes which are already in existence. And this is fundamentally the concept behind Project Cyclops. The construction of a large number of radio telescopes all interconnected to a central computing facility so that they act in unison, is the solution to the problem, or at least, a partial solution to the problem of sensitivity and distance. Furthermore, this kind of a concept would allow one to start with a very small array first, two or three or ten, and expand it out until an optimum system was reached, or until a successful contact was made.

Now, in addition to… Okay, let me just mention that to build this kind of an array does not take any new technology. These are standard radio telescopes, made of the same kinds of materials and of the same size as exist today. Now, there are a number of problems that you have to attack in some sort of an order in order to be able to mount such a search. One is to decide where in the region of the expected signal to look for intelligently contrived signals. What I show here is a graph that has here the noise in the radio spectrum as a function of the frequency of the electromagnetic radiation. What this indicates is, that if you look at this line here, it indicates that at the very low regions of the spectrum, there is a lot of background noise. Similarly at the high regions there is background noise also, and or interferences by atmospheric water and oxygen. However, at this region here there is a minimum. So if we're going to look for signals in the electromagnetic spectrum with radio telescopes, this would be the region we would want to look because this is where we would get the greatest sensitivity. Now it also turns out that this region is bounded by two lines: a hydrogen line, hydrogen the most abundant element in the universe, has a signal at this particular point in the spectrum. Hydroxyl, another common ion in the universe, has a signal here. Now you'll associate the fact that hydrogen and hydroxyl are the components of water. What this says is then, people conveniently call this region the "water hole." For obvious reasons. Poetically, it is a place where water-based life could seek its own. More importantly, scientifically, it happens to fall in a very quiet region of the spectrum. And if we're expecting weak signals, we don't want to look out in an area where we have a lot of interfering noise, where we have a noise problem. So, that's one kind of problem that people are struggling with, if we mount this kind of a search, technically, where do we look for these signals? How can we best improve the statistics of our chances of detecting it? Can I have the slide off, and the lights for a few minutes?

In addition to considering questions like the telescope array as well as where to look in the electromagnetic spectrum, other things that are being considered are the philosophy behind such a search, perhaps alternative methods of conducting the search, the resources required, and so on. One other interesting study that's proceeding is a catalog of stars, to try and identify some suitable targets. Stars are being cataloged according to their luminosity, according to their lifetimes, so that we can whittle down this tremendous number of stars, into some workable number of target stars: stars that would be likely to have planets about them. Stars that are too bright, based on our own analogy and our own solar system, would have too much radiation, too much heat to support life on planets around them. Stars that are too weak would not have enough. Stars that have a lifetime shorter than four and a half billion years, for example, would not have enough time for their planets to evolve life as it evolved on Earth, and so on. We start applying criteria like this to stars and you can start whittling down this tremendous number of stars into a workable number, so that you can establish targets to search. Then you have an array like this and you search each of these in sequence, for a given period of time, and look for signals. In addition, on a more practical level, an approach that has a much wider application, is that new telescopes are being devised to fly in space in the shuttle and other programs, which may be able to detect planets around other stars directly, by direct visualization of planets. Right now you'll recall we only have inferential evidence that there may be planets around other stars, based on their motion. However, advances in techniques associated with the visual telescopes may permit us to directly visualize planets about nearby stars, by making adjustments to the telescope so that the background light is adjusted such that you can see the difference between a very bright object, namely the sun, and a very dim object, namely the planet in orbit around it, at very close distances.

Okay, I'd like to move on now to talk about the other half of the coin that I was talking about, namely the search for life within our own solar system. First question that comes up is: where do we look? Now, we have our nine planets and countless moons, not countless moons, but a large number of moons, especially orbiting the outer planets, the giant planets. The question is, which are good candidates for the search for life? Well we feel that the inner planets, Mercury and Venus, are too hot to support life. Mercury, in addition, doesn't have an atmosphere. The temperature on the surface is unbelievably hot. Venus also has high surface temperatures, has a very dense atmosphere, composed mainly of carbon dioxide, which is not inhibitory to life. However, the atmosphere also contains high concentrations of sulfuric acid, which is not too good for life. At all. So, our suspicions are that the inner planets, for the reasons of temperature, composition, and lack of atmosphere in the case of Mercury, are not suitable targets. Now our own moon, we know, never harbored life. The Moon's soil has been tested extensively here, in our laboratories, and we feel that conditions probably were not even present on the Moon to ever allow chemical evolution to occur. It probably never had an atmosphere. And so these processes of chemical evolution that I talked about earlier were not able to occur there, nor could they occur in the future.

Move out to the outer planets: Jupiter, Saturn, Uranus, Neptune. We believe that these planets are all basically similar in composition, although of course we know the most about Jupiter, which is the nearest one of the outer planets. Jupiter though, we don't know if it has a surface. Certainly it has a very dense and turbulent atmosphere. The interesting thing about Jupiter is that that atmosphere is composed of methane, ammonia and water. And you'll recognize those compounds as being the compounds that we postulate were present on the primitive Earth. So what this says is that Jupiter today may be a juvenile Earth. Jupiter today may be what the Earth was 4 billion years ago. Certainly there are extensive energy disturbances in the Jovian atmosphere, we know that from our spacecraft flybys. So, we have no doubt that at least organic synthesis is occurring on Jupiter, and we're waiting very anxiously for the day when we can send a spacecraft there to probe the atmosphere, instead of just flying by it, to try and see if we can identify organic compounds, and organic compounds similar to the kind that we believe occurred on Earth as a result of the process of chemical evolution. However, the question of life on Jupiter is open. If there is life on Jupiter it would have to be airborne, because of the lack of surface, and that is not inconceivable, but it's certainly not optimal. Then you move out to the other planets, Saturn, Uranus, they're probably too cold. They don't receive enough energy from the Sun to allow life as we know it to exist. So that leaves us with Mars. Now, Mars is both very similar and yet very different from the Earth. Mars is about half the size of the Earth, Mars has about one-third the gravity the Earth has, Mars has an atmosphere. That atmosphere is very different. The Martian atmosphere is thin, composed mainly of carbon dioxide. Our atmosphere, by comparison, is very thick, composed mainly of oxygen and nitrogen. Mars has a day/night cycle, just like the Earth does, and in fact it has a day cycle of twenty four hours, almost identical to Earth. Mars exhibits the four seasons like the Earth does, because of the inclination of the planet to its orbital plane. In the wintertime, the polar caps increase in size, and in the summertime they decrease. The caps recede.

The temperature extremes on Mars are very different from those on Earth. If you're on the equator on Mars, on the hottest day of the year in the Summer, the temperature at the hottest part of the day would reach a balmy 62 degrees Fahrenheit, and at that same place the same night, the temperature would drop to below 100 degrees Fahrenheit. Below -100 degrees Fahrenheit. So, there is a continual freeze/thaw cycle on the whole planet, all the time. Now you'll say: "Well gee, that doesn't sound too good for life." And it certainly is harsh by terrestrial standards. But, we've exposed terrestrial organisms, microorganisms, to these kinds of conditions in the laboratories. And we find that they survive. And in fact they grow, when they're not frozen. You can make Mars simulation boxes, we call them "Mars boxes," where we simulate the sunlight impinging on the planet, we simulate the low water, we put in carbon dioxide, reduce the pressure, cycle a temperature, freeze and thaw it every night, and put organisms in there. And they grow. They don't flourish like they do here on Earth, but they don't die either. They don't completely die off. As a result of that, we've taken very extensive precautions to sterilize the Viking spacecraft so as not to contaminate Mars with those organisms. So, the point is that although the conditions on Mars appear to be harsh by terrestrial standards, if a biologist is impressed by anything, it's the adaptability of life on Earth, especially the primitive life forms like microorganisms. So it's not inconceivable that microorganisms could survive under the conditions as we presently know them from Mars. Furthermore, what if those organisms evolved under those conditions for billions of years, like we did on Earth?

Now, one other interesting aspect about Mars is… Well, let me backup for one minute. You'll recall that I said that we believe that the atmosphere of the Earth, primitive atmosphere, was composed mainly of methane, ammonia, and water, a very reduced atmosphere, and that organic chemical evolution occurred as a result of energy sources interacting in that kind of an atmosphere. And you'll say: "Okay, but you just said that Mars has carbon dioxide in the atmosphere, you didn't mention methane and ammonia, and methane and ammonia are not present." So the question is, do we even expect that Mars could have undergone chemical evolution? The answer to that question is yes. If we simulate the current Martian atmosphere, which is carbon dioxide, carbon monoxide and water, and subject that atmosphere to ultraviolet radiation, which is certainly present on Mars from the Sun, in the presence of some sort of a catalytic surface, like soil or ground glass, we find that organic molecules are synthesized, even under those conditions. And in fact, some of the same compounds that are found in interstellar space, in the meteorites, and in living systems. So, we feel that even under the conditions that are existing on Mars today, that there may be, occurring right now, or have occurred in the past over geological time, chemical evolution of one kind or another.

Okay can I have the lights, please? I'd like to show the next slide.

This is a picture of Mars, which, as I've indicated, is our likely target. A target in the solar system that we feel, right now, is most likely to harbor life. This is taken from Earth, and it's a very beautiful picture, and it's very different from the kinds of photographs you've probably seen in the papers from the flybys. The flybys of course, taken at very close range, show that Mars looks a lot like the Moon, except that the most recent flybys have really rekindled our interest in the planet, because they show that the planet is not dead, the planet has, or has had in the recent past, volcanic activity, that the planet has or has had in the past extensive water erosion. These things are important for chemical evolution and for life. Two spacecraft have been launched, one in late August and one in early September, on their way to Mars. The trajectory is 505 million miles, take 11 months, and the first lander is scheduled to touch down on the surface on July 4th of 1976, the second lander some six or seven weeks later. The mission is a fairly comprehensive one, it's a combination orbiter and a lander. When the spacecraft reaches Mars, the lander will separate and descend to the surface for a soft landing, the orbiter will continue to go around the planet and act as a relay station from the lander to Earth, as well as do scientific experiments of its own. The lander will descend to the surface and complete a soft landing, and then it will carry out some thirteen scientific investigations aimed at increasing our general knowledge about the planet Mars with special emphasis on the question of life.

I've listed here just a summary of the science that's occurring on the Viking mission, I'd like to just point to a few of them to give you an example of the kinds of things that are being done. Let me just concentrate mainly on the lander portion, which you see here, there of course is a biology experiment, the life detection experiment, which I'll describe in just a moment, there's a molecular analysis experiment. This experiment is very important. The purpose of that experiment is to see if there are, in fact, any compounds, any organic compounds, in the Martian soil. And we believe that that experiment should detect them, based on what we know about the potential for the Martian atmosphere to result in the synthesis of organic compounds, we believe we should be able to detect them with this kind of an experiment. This kind of an experiment, this kind of instrument in fact, was used to detect organic compounds in the meteorites. So, it in and of itself of course though, is not a life detection experiment. If it detects an amino acid, for example, the same kind of an amino acid that we have in our bodies, that in and of itself is not proof for life. Because, as I've indicated before, we can get an amino acid formed abiotically, that is without non-biological systems. But, the combination of the biology experiment with the molecular analysis experiment will make for very strong interpretations about the current state of chemical evolution on Mars, the potential for life, the possibility of extinct life, or the possibility of existing life. In addition, there will be TV cameras that could see elephants if they're present on the planet, obviously we don't expect macro lifeforms, but if there should be macro lifeforms, that is, lifeforms visible to the naked eye, the cameras will see them, the cameras are about as sensitive as your eyes. If you're standing on the lander, and you can perceive a pebble the size of an aspirin on the floor, that's about what the camera will see, at that distance. And the same thing looking out at the horizon, whatever you can see and discern at various distances, that's about how sensitive that camera is. In addition, there's meteorology, meteorology of course is important for life as well. We'd like to know, what are the precise conditions of wind, temperature, speed, and direction, at the landing site. There's seismometry, which will measure Marsquakes. This will tell us about the internal structure of the planet. Then in addition, there are magnetic experiments and physical experiments that'll tell us about the structure of the soil, the content, and tell us something about how the crust of the planet evolved.

So you can see that in a number of these experiments that I've talked about, the information that we gain will be very relevant to the question of life. One other one that is not listed on here is an inorganic analysis experiment, this experiment will take Martian soil samples and instead of looking for organic compounds, will look for the presence of salts and other materials that are essential for life on Earth. We really don't have an analysis of Mars soil. We don't know whether there's biology there, we don't know whether there are organic compounds there, we don't know whether there are even salts and minerals, or what they might be. So, all of these experiments then will work in unison to give us a very good characterization of the surface of the planet.

This is an artist's conception of what the lander looks like. It hardly looks airworthy, but they assure us that it'll make it. It's a three-legged beast that will descend from orbit on a parachute and then perform the final descent with retro rockets, to a soft landing. Some of the characteristic features are the sample arm, which will go out and dig out a sample, and then deposit it back into the lander itself, where the biological, inorganic, and organic analysis will be performed. The two TV cameras are right here, this one, and this one. The spacecraft is powered by radioactive sources, that generate heat and then electricity, these are located here, this big box, and that big box. This is a meteorology sensor, that's an antenna to relay information to the Earth, and then the rest of the experiments are located interior to the spacecraft. The unit itself stands about seven feet tall, and is maybe ten to twelve feet across. It weighs one half ton. So the lander itself is really an automatic laboratory.

This is a picture of what the actual biology flight instrument looks like. This particular instrument is on the first Viking, the Viking that was launched in August. The biology instrument itself is roughly one cubic foot, and it weighs about 35 pounds. And it carries out three experiments. And that's it, that box contains everything. Contains the cells in which the experiments will be performed, contains all the electronics and the mechanical subsystems, the data collection systems, and so on. It's a complete entity in itself, and it's never been built before, that's a one of a kind instrument.

Now I'd like to spend just a few minutes telling you what this instrument is going to do on the planet. Now, we're going to Mars, to look for primitive lifeforms. And in order to design a life detection system, we have to really go by the only lifeforms that we know anything about, mainly terrestrial. So by definition, the experiments that we have on the Viking mission are very geocentric. That is, they're oriented very much to Earth life as we know it. Microbial life. So essentially what we're sending to Mars are three experiments, designed to detect microbial life that would have a metabolism similar to the kind of metabolism exhibited by microbes on Earth.

Now, to take these experiments one at a time, the first one is called the paralytic release experiment. This experiment is essentially a photosynthetic experiment. We incubate a soil sample from Mars, with radioactive carbon dioxide, in the presence of light. Here on Earth, of course, plants take in carbon dioxide in the presence of light, convert the carbon dioxide into organic matter, and evolve oxygen. Well on Mars, we know there's plenty of carbon dioxide, it certainly gets bombarded with plenty of sunlight. If there are organisms there, the guess would be that they would utilize that carbon dioxide and convert it into organic matter. So what we're looking for then is the transfer of the radioactivity from a gas form, into a solid form, that then gets embedded in the organisms in the soil. Then we'll take the soil, and heat it at very high temperatures, and try and drive off the organic material, and then count the amount of radioactivity that's present. The appearance of radioactivity in that organic manner will then be indicative of a life process, converting the gas into some sort of a solid material.

The second experiment, called the labeled release experiment, is essentially the reverse. Instead of starting with carbon dioxide, and looking for the formation of organic material, we're starting with organic material, labeled with radioactivity, which will be, as it shows here, dribbled onto the Martian sample. If there are organisms there, and if they behave like terrestrial lifeforms, they'll utilize those nutrients and expire carbon dioxide as an end product of their metabolism. The carbon dioxide will be a gas, and will be radioactively labeled, and be detected here. So the detection of labeled carbon dioxide, then, will be indicative of life processes converting organic material into waste products, metabolic products like carbon dioxide.

The third experiment is perhaps the most geocentric, or Earth-based experiment of the three. That is, it's called the gas exchange experiment. The soil sample is incubated with a nutrient medium that is very rich in all kinds of things, it's actually called "chicken soup" by the experimenter, it is loaded with amino acids and sugars and some carbohydrate material, it has salts, it has vitamins thrown in, things that terrestrial organisms just go goofy over, just overpower the whole system. 'Cause I mean look at it, we'd hate to go to Mars and not test for the obvious, not test for life that is almost identical to Earth life. So this really represents, well, let me get back to that in a minute. At any rate, the philosophy behind the experiment then is:

you feed the soil and organisms a very rich nutrient, and then you monitor the atmosphere for products of metabolism. Not only things like carbon dioxide, but hydrogen, nitrogen, methane, depletion of oxygen, and so on. So what it really is is simply a measurement of the atmosphere above the soil with time, in the hopes of seeing changes in gas composition and these changes will be measured by an instrument called a gas chromatograph. Now, what I was just going to say a minute ago was that these three experiments really represent extremes, okay? The paralytic release experiment is perhaps the most Mars-like experiment we can think of. It operates under conditions that are essentially Mars-like. We're not making any extraneous additions, we're not putting anything in there that isn't on Mars already. On the other hand, this one is the most Earth-like experiment. And in this case, this one can be run dry or wet, this one can be run moist or very wet, and so on, in this case it's a very dilute nutrient medium, in this case it's a very rich medium. The point is, in these three experiments we've tried to cover as many possibilities as we can. This is our one big shot, and in trying to arrive at a slate of experiments that would do the best job for us, we tried to cover as many variables as we could, tried to build into each experiment as much capability for changing what we're doing, depending on the results as we could. So that we could cover as many bases as possible. And we tried to outguess Martian organisms a little bit, but on the other hand we want to not forget about the possibility that there may be lifeforms that are similar to Earth.

Can I have the lights, please?

Okay, so, that's the Viking experiment. I think that we should all realize that Viking is really the first step. It would probably take many more missions, perhaps even a return of a sample from Mars before we could really, conclusively say with very hard, scientific facts to back us up, that there is or is not life on Mars. But if we do go to Mars and after some logical sequence of experimentation, discover that life is present there, but that it differs from terrestrial lifeforms in some minor ways or even some fundamental ways, this would significantly broaden our concept of life and the origin of life. If we go to Mars and we find life there, and find out that it's the same as Earth life, this raises two very interesting possibilities. One is the possibility that Earth life and/or Martian life was seeded, seeded, from some common ancestor or precursor. The other possibility, which is the one that I would favor and I think many of my colleagues would, is that if we found life on Mars and found it to be very similar to Earth life, we would tend to believe then that the processes of chemical evolution that I described earlier, that is the interactions of organic molecules and their subsequent evolution, really tend to proceed along very restricted lines, that these kinds of reactions are not random, are not chance, but that there are some fundamental properties of the matter and of the compounds themselves, that lead them along very discreet lines, and result in from one step to the next, in very similar types of compounds and processes and ultimately life.

Now if we go to Mars and don't find life, but do find that the Martian environment is not inhibitory to life as we understand it, and even find that there might be organic compounds present, then I think an equally intriguing question arises. And that is: why not? Thank you.

[applause, clamoring as people leave]

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: The question was: "What about the possibility for macro, or large forms of life on Mars?" I feel that the conditions on Mars are harsh enough, say, to prevent or inhibit the development of macro forms. I believe that if there are organisms present on Mars that they would be microbial, be very simple, be very adaptive. We know a fair amount about the environment of the planet, the temperature changes, like I've indicated, the very low amounts of water that are present, the lack of oxygen, the lack of an ozone layer to shield out the ultraviolet radiation. Those things are pretty tough for advanced lifeforms. But not so for microorganisms, necessarily. So that's why I feel that we're probably very right in looking for primitive lifeforms on that planet given the environmental conditions. In terms of the origin of the atmosphere of the planet, which you also indicated in your question, I don't think I have an answer to that. It is interesting that when you look at the atmospheres of the planets in the solar system, that the outer ones are very similar. But then you come to the Earth, with its nitrogen oxygen atmosphere, come to Mars with a very thin carbon dioxide atmosphere, go to Venus with a very thick and dense turbulent carbon dioxide atmosphere, to Mercury with no atmosphere. Try and rationalize all this back to how did all these planets form, did they really form from this common gas cloud? It's tough. But don't forget that we're dealing also with processes of escape of primitive atmospheres from the planets, the fact that Mercury is so close to the Sun, resulted probably in its initial atmosphere being boiled off very rapidly. The current atmosphere of the Earth is probably the result of biology, it is the result of biology. What about the current atmosphere of Mars? I don't know. [pauses] Yes?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: The question is that some of the moons of Jupiter are massive, in fact very similar to the size of the Earth, and what about the potential for those bodies harboring life? I'd say that probably it's felt that the moons of Saturn are more likely candidates. One in particular, Titan. Titan apparently has, well, speculation is that Titan has water in its atmosphere, that it may even have a temperature regime that is not too cold, because of its distance. And I think of all of the moons of all of the outer planets, Titan is probably the most likely to at least perhaps have some chemical evolution and the potential for life. You see, the problem is that the further out you go, the more trouble you're in in terms of energy sources for life. Yes?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: Yes. The Soviets attempted a number of landings on the planet Mars over the last couple of years, we know for a fact that at least one spacecraft missed the planet, it didn't go into orbit. And it turned into a flyby instead of a lander. In the other case, they succeeded in putting a spacecraft down on the surface which functioned for only a few seconds. They made a very significant discovery, a discovery that implicates that there may be argon present in the Martian atmosphere. This would tell us a lot about the origin of the atmosphere of Mars if that fact holds up to be true. Their spacecraft did not contain any life detection experiments. We know that […] to say that our own space program has told us much more about Mars than the Soviets have. Especially the knowledge that we learned from the Mariner, where we were able to orbit the planet for 90 days or longer, be able to observe seasonal changes, be able to observe the dynamic changes of the atmosphere and the dust storm and so on. As far as we know, they are still very interested in Mars, but they've been unsuccessful in soft landing. So we're next. Yes?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: The first Viking will reach Mars on June 19th. It'll go into orbit on June 19th. So we have, from the 19th to the 4th, if that's the nominal landing date, two and a half weeks or so. Spacecraft can actually be kept in orbit much longer than that, can be kept up to perhaps a month or two before you finally separate the orbiter from the lander and put the lander down on the surface. So there's quite a bit of flexibility in how long that thing could be kept in orbit should there be something like you suggest, another dust storm occurring. Yes?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: That's a good question, the question was: "Have we made attempts to communicate?" That's obviously, there's two sides to the coin, and I guess I probably didn't mention that in the course of the talk. The kind of thing that I was talking about here was eavesdropping. Snooping. Looking for either beamed signals, or artificial signals. If somebody was to look at Earth with this kind of a system they'd certainly see remnants of our TV broadcasts [recording is cut off at 1:03:55]

[recording resumes at 1:04:37]

Drake and Sagan together have developed some sort of a cryptogram that you could send that tells how big we are and where our star is, where our sun is and so on. Whether we've actually done that or not, actually sent specific messages like that, I don't know. But they've certainly thought about it, considered what kind of a message to send, used binary systems and so on.

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: The... [pauses, audience member continues speaking] That's right. [pauses] They could be very localized disturbances. I don't know that we have a, well, I don't know that we have a good explanation for the origin and longevity of the dust storms. Does anybody? Bob, do you? Do you know about that? Oh, it lasted weeks? Yeah. That's correct. It was violent. The atmosphere is thin, but… [pauses, muffled speaking from background] Mhm. No, I don't know the answer to that question. Yes?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: Well, hopefully there won't be much disturbance at all. There's actually two things that could happen: Number one, the ground could be sterilized. Number two, you could deposit on the ground, organics from the exhaust fuel themselves. Of course, we've got an instrument looking for unsterilized life, and we've got an instrument looking for organics. There was some very extensive testing done in simulated Mars conditions in chambers, that show that when the retro rockets fire, the plume that they give out is very narrow. It's a very thin plume that does not spread out very far, because of the temperature of the planet and because of the composition of the surface, there's not much in the way of radiation of heat outward. And then, in addition we've got the telescope arm which can go out many feet to collect the sample away. In addition, they're using a fuel, I'm not sure what it is, but they're using a fuel that will not be loading the surface with huge quantities of organic materials. And even if they do, we know what those organics are precisely, and we'd be able to subtract those out from the background. Yes?

AUDIENCE MEMBER: How much research is being done to create life in the laboratory?

DR. DEVINCENZI: I don't know. We hear reports… It depends… [pauses, unintelligible speech from background] Pardon? Pardon?

AUDIENCE MEMBER: [unintelligible]

DR. DEVINCENZI: It depends on what you define as life. Do you define a macromolecule, or, say a strip of nucleic acid that can attach another strand to it and duplicate a copy of itself, is that living? Or does it have to be the formation of a cell which then divides and forms another one? Nucleic acids can be reproduced in test tubes, yes. I don't know if you would call them living or not. Some of the reproduced copies have biological activity. Certainly there is research along those lines going, I thought you were asking whether or not, what kind of progress is being made towards the synthesis of an entity, a cell, a unit, that can then metabolize and reproduce and divide and so on. Along those lines, what I've indicated here is the extent of the synthetic approach. Taking the degradative approach, you can start with cells, break them apart into their component pieces, put them all back together again and you can get functions established again. So those kinds of studies are going on, but in terms, when people talk about the synthesis of life in a test tube, they mean starting with nothing and ending up with a cell that replicates and reproduces itself. Yes?

AUDIENCE MEMBER: [unintelligible] …sterilized craft, I was just wondering what it had to go through to ensure that it would be sterilized?

DR. DEVINCENZI: At each step of the way, during the construction of the biology box, it was all constructed in ultra clean rooms, to start with. Then each piece was cleaned and the surfaces monitored for bacterial load, and as units were assembled, the whole box was gassed, and cleaned again with solvents, sealed, then when it went into the lander, the whole lander was sterilized by heat in a bioshield to prevent it from being recontaminated again. And the final sterilization regime was something like 113 degrees centigrade. Which is 250 degrees Fahrenheit, for 40 hours. Which is pretty high. And of course the instruments were designed to withstand those kinds of temperatures. But very stringent precautions were taken. And according to the agency, at least, the Viking is the cleanest spacecraft that's ever been launched from Earth. [pauses] Yes?

AUDIENCE MEMBER: What exactly is the life expectancy of the lander when it gets there, and how many times can samples be cycled through biology experiments?

DR. DEVINCENZI: Yes, the question was: "What is the life expectancy of the lander, and how many cycles will it perform?" The nominal lifetime of the lander is 90 days, roughly. During that time it'll perform four 15-day biology cycles. Each of these three experiments will be performed four times, each cycle over a 15-day period. If there's a positive result, on any one of the experiments, the capability exists to go back and take the same soil sample, sterilize it and repeat the experiment as a control. To see if you can abolish the signal. Now, it turns out that the spacecraft really is limited by power. And there is talk right now, that we know that there is enough power stored in the spacecraft that it can operate a lot longer. And what we really may be dependent upon are the expendables, like the nutrient supplies, the gas supplies, and things like that. But nominally, the mission is 90 days, they are talking of an extended mission, during which we might instead of cutting off one of the biology experiments or doing it a fifth time, just let it sit for another 30 days, without having to add any more nutrients, to see if maybe the time factor will elicit a biological response. [pauses] Yes?

AUDIENCE MEMBER: Are there forms of radiation that travel faster than light?

DR. DEVINCENZI: Not that I know of. Are you thinking about interstellar communications and the possibility of contact? No, you know, when we're talking about projects like Cyclops and interstellar contact, you know we're talking lightyears. Lightyears, distances. [pauses, unintelligible speech from background]

[applause; program ends]