IN SOLEMN SILENCE

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I shall talk tonight about recent developments in an old subject, which is, the eternal curiosity of human beings about the stars and about the possibility of life in other worlds. Our ideas on these subjects have changed rapidly because of many recent scientific developments, including radio telescopes, theories of formation of various celestial objects, such as galaxies, quasars, and black holes, and the current surge of new knowledge in molecular biology.

The idea of possible life in other worlds has been most important for popular support of America's space program. It also has led to a great out-pouring of science fiction, including movies and television shows with people on space ships. Another form of science fiction is called "unidentified flying objects". From these mythical vehicles emerge the little green men with built-in radio antennas, and more deadly fabrications such as the "Andromeda Strain".

In making the case for the existence of intelligent life elsewhere in the universe, the usual procedure is to admit that the probability of such life occurring at any given location other than the Earth is exceedingly low, but to offset that concept, we note that our galaxy contains some hundred billion stars. Beyond our galaxy lie other similar galaxies, each containing about a hundred billion suns. These are the major units of creation. The average separation between any two galaxies is about a million light years.

It seems that every advance in astronomy brings news that the universe is far vaster than was previously thought. The number of galaxies is now estimated in billions. These new concepts mean that there are increasing possibilities for the existence of earthlike planets that are suitable abodes for life.

At the same time, new evidence of early forms of life on our own planet leads to a broader appreciation of the role of evolution in the emergence of intelligent forms of life. Moreover, the study of evolution is now becoming occupied with comparisons of DNA molecules. Knowledge of DNA has revolutionized the entire scope of all fields of biology. We are steadily approaching the point where many of the characteristics of an animal, plant or microbe will be considered in terms of the sequence of nucleotides in its molecules of DNA.

Recent developments in cosmology are so remarkable in their scope that all of us must re-examine our thoughts on the universe and its history, including the appearance and development of life. The diagram is taken from an article by Professor Eric Chaisson of the Center for Astrophysics jointly supported by Harvard University and the Smithsonian Institution. The diagram shows time in a way that is unfamiliar to ordinary thinking, namely in a non-linear plot. The initial explosion is shown as having taken place at zero time. During the next 10^{-23} seconds, which is the amount of time it takes light to cross the distance of one proton, the average density of the universe was 10^{50} grams per cubic centimeter, and an average temperature greater than 10^{30} K. What followed next was the Hadron epoch. Hadrons are the heavy elementary particles such as protons, neutrons, and mesons. They collided and interacted with one another during the first second of existence of the universe and produced a fireball of radiation consisting of high energy photons. The next epoch was about a millisecond after the bang and the lighter elementary particles such as electrons neutrinos and muons became predominant. The average density of the universe had now decreased to about 10^{10} grams per cubic centimeter and about 10^{10} degrees K.

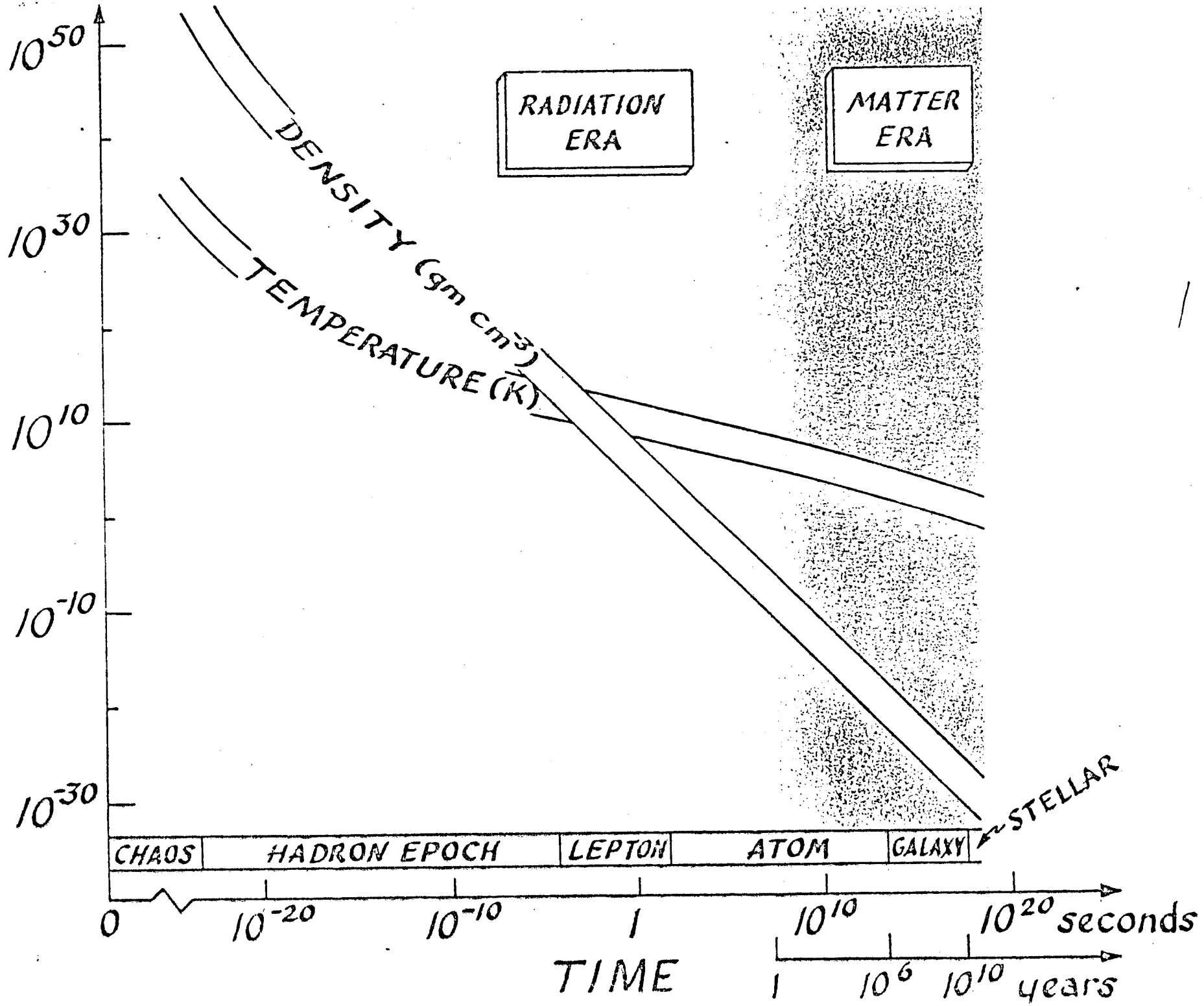
The next major epoch is known as the atom epoch. It extends in time from about 100 seconds to about a million years after the bang. At the beginning of the atom epoch, radiation still reigned supreme over matter, for the universe remained flooded with photons. Sometime between a few minutes and a million years after the bang, the charged elementary particles of matter became able to form atoms. Hydrogen was the first type of element to form and it is still the commonest element in the universe. Hydrogen is the ancestor of all other elements, and hence of all things. Matter became dominant over radiation.

Then came the fifth epoch, in which the galaxies formed. None have been formed within the past 10 billion years. The universe became thinner, colder, and darker, and entered into the present stellar epoch. This has lasted between

ten and eighteen billion years, and the average temperature of everything in the universe is at present 3 degrees Kelvin. This residual temperature is the remains of the fireball that occurred at the time of the big bang.

During the stellar epoch, the heavy elements were formed, life originated on the earth and probably elsewhere, and, within recent years, human beings appeared, so that the way was finally opened for the development of culture and technology.

This grandiose scenario is a great stimulation to awaken interest in the possibilities of intelligent life elsewhere in the universe, and to stimulate scientists to devise ways of detecting life elsewhere.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Our first topic is a comparison of stars of various sizes to decide which stars could furnish the right type of support for a planet on which life could develop. There is no lack of stars, there are about 100 billion in our galaxy and there are 100 billion galaxies. How can we specify the nature of the central star in a solar system that is to contain intelligent life?

The fundamental properties of stars include surface temperature, mass, evolutionary history, and rotational velocity. A concept necessary is the time that a star spends on the main sequence. This is the time that a star is in a stable state with respect to radiation output and temperature. The main sequence is preceded by early evolution, and is followed by collapse of the star with cataclysmic results. At this point, we may relax; our star, the sun, is in the middle of its main sequence of about 10 billion years.

The length of life of a star depends on its size, measured as its mass. The larger the star, the higher its surface temperature, and the shorter its length of life. A star that is one and a half times the size of our sun, will have a lifetime of only two billion years, which is not long enough for the evolution of intelligent life on one of its planets. The larger stars have other properties that are disadvantageous to life, such as excessive radiation.

Stars that are less than 80% of the size of the sun are not suitable for planets that will develop life, because these stars do not give off enough radiation to produce the organic compounds required on the planet for the origin of life. Also, a planet that was orbiting a small star would have to be very close to the star to get enough light and heat. But, when the planet gets close, the star will raise huge tides on the planet. These will slow down the rotation of the planet so that the same side will face the star at all times, just as the moon always faces the earth. The oceans on the near side would boil away, and on the far side they would freeze, which would make it impossible for intelligent life to evolve, because the water would all migrate to the back of the planet.

Another problem is the angle of the axis of rotation of the planet. This

will affect the length of the seasons.

For example, on the planet Uranus, there is no sunlight during the winter, and the sunlight during the summer is twice that at the Equinox.

The general conclusion is that the only stars that have continuously habitable zones around them are those between 80% and 120% of the size of our sun. There are reasons for narrowing this range to between 90% and 110% of the size of the sun.

Other stars that must be excluded are all stars that are members of multiple star systems that result in extreme thermal cycling. This throws out about 70% of stars.

Our constraints are, therefore first, the star must be on the main sequence (90%). Second, it must be a single star (30%). Third, the star must have a mass between 90 and 110% of that of the sun, and it must be more than 4 billion years old, for life to have developed on one of its planets. These constraints are fulfilled by only one percent of stars. Next, the star must have an extended equatorial disc containing the right kind of materials, including magnesium, silica, sulfur, iron, sodium, aluminum and calcium, to make a suitable planet that is earthlike.

We then calculate the fraction of stars that meet the preceding requirements and also are accompanied by a planet of between 25% and 200% of the mass of the earth in an orbit of appropriate radius and eccentricity, and having a spin angular velocity and orientation that could have been earthlike for 4 billion years. This fraction is between one half per cent and one fiftieth of one per cent of the preceding stars that have qualified.

The final calculation says that there may be between 1 and 100 earthlike planets within a distance of 1,000 light years, according to Dr. William G. Pollard, in an article that appeared in the American Scientist for Nov/Dec 1979.

Other calculations range as low as 10 for the number of intelligent communities

within our galaxy that would be capable of communicating with us to as high as 50 million. The higher figure assumes that a civilization can overcome its crises and last for more than 100,000,000 years, which is difficult to reconcile with the process of evolution.

It is interesting that most of the fantasies about intelligent beings from outer space show them as having many human characteristics, but often being more intelligent, free from problems, living indefinitely, and infinitely wise. Such anthropocentric images, in earlier cultures, were often called gods.

I shall not attempt to discuss or even mention the various types of fantastic creatures that inhabit the pages of science fiction.

How shall we look for other worlds? By space travel, by means of unmanned spacecrafts, or by sending or receiving radio messages?

In science fiction, the favorite method for visiting other worlds is by means of manned spacecrafts.

Let us seek the advice of engineers. The nearest star is over four light years from us. This means that any round trip to it completed in the working lifetime of a human being, about 40 years, requires us to travel at a speed at least one fifth that of light. The payload of the spaceship would be not less than 1,000 tons, including the engines, auxiliary power systems, control, communication and guidance equipment, repair shops, cruise quarters and life support systems. The energy required to accelerate the ship to one fifth the speed of light, and maintain it for the trip to the nearest star would correspond to about 1,000 years of total energy consumption by the United States. For twice as long a trip, the results would not be available to the people who paid for the launch, the spaceship would have to be enlarged to contain a nursery and educational facilities, and as Dr. Bernard Oliver notes, the second generation would probably mutiny, judging from the general behavior of children.

The conclusion is that space travel will have to stay in the realm of science fiction.

The next possibility is to replace the spaceships with automatic rockets, carrying detection equipment that will radio the results back to earth. These might weigh about 10 tons. However, it might be politically impossible to get funding if the results were not to appear for centuries.

The energy requirement of the search would be measurable in multiples of the annual United States consumption of energy. Obviously, under current conditions of energy shortage and conservation, the search would be impossible.

The sensitivity of radio telescopes has reached the point that ground based systems can be built that will detect a gigawatt on the directional beacon or its equivalent at a distance of 1,000 light years. This corresponds to a flux of one photon per second per square kilometer between the hydrogen and hydroxyl lines in the microwave window. This is between 18 and 21 cm (1.42 and 1.72 gigahertz) wavelength. This is a region where the galactic noise and the noise produced in the earth's atmosphere are at a minimum. It is sometimes humorously called "the water hole", because hydrogen and hydroxyl combine to form water. The idea is to look by means of automated recognition systems for patterns in the signals received. This method is the one that is currently preferred in the search. It is comparatively inexpensive, and it can be started by using existing equipment.

The search for extraterrestrial intelligence seeks to evaluate several variables, some of which are unknown and can only be estimated. One of these is the question of the existence and properties of other planetary systems within our galaxy.

The only examples of life known to us apparently originated and evolved on a planet, our own planet the Earth. We do not know whether life can originate in the absence of a planet, and we have no reason for supposing that such can be the case.

One line of research, therefore, concerns the detection of other planetary systems in outer space. There are additional reasons for conducting such a search. First, its results will help us to understand the origin of the solar system. Unless we know something about the frequency of planetary systems and their general property, we cannot test the various theories as to the origin of the solar system. The results of such a search will also have a bearing on the question of the formation of stars, because the usual theory is that planetary systems are often a by-product of the formation of a star.

At present, there is no unambiguous evidence for the existence of other planetary systems according to Dr. David C. Black.

It is not possible to see planets at the distance of the stars, even the nearest star. A method for detecting the existence of planets is by studying perturbations in the orbit of a star. This is called astrometry. Some years ago, it was thought that several stars had been found to have planetary companions. Three of these stars were Barnard's star, 61 Cygni, and 21185 Lalande. These stars in a celestial handbook revised as recently as 1977 were supposed to have planetary companions, because it was thought that a wobble had been detected in their pathways, when the apparent position of the star was followed as a function of time. An astronomer named Van de Kamp concluded that Barnard's star showed behavior consistent with either a single dark companion of mass comparable of that to Jupiter, revolving about Barnard's star with an orbital

period of twenty four years in an eccentric orbit, or with two dark companions about as large as Jupiter, moving in orbits of 12 and 24 year periods.

However, Hershey noted that there were small sudden changes in the apparent position of other stars that were examined by the same telescope. These changes coincide with time when there were adjustments and alterations to the telescope. The data on Barnard's star taken with two other astrometric telescopes did not confirm the perturbation that was reported by Van de Kamp. Astrometric telescopes are refracting telescopes, and they use a lens instead of a mirror. Even the slightest shift in the lens can grow into a large distance in the photographic plate. Such errors are now thought to be responsible for conclusions that have been drawn about planetary companions to stars. New technologies are on the way, and there is a project to design a new astrometric telescope that will be 30 to 50 times more accurate than existing systems.

Another possibility is that the star would be dimmed when a planet passes between it and an observer, something like an eclipse of the sun. In principle, this could be detected by photometry. Of course, in the case of a large planetary orbit, a transit of the planet across the face of the star would be an exceedingly rare event. It would be quite difficult to detect the planet by direct observation, because the star would be so much brighter than the planet.

To give an idea of the difficulty of detecting a planetary system by astrometry, we may use the example of the possibility of detecting the wobble in the motion of the sun due to Jupiter at a distance of 33 light years. The angular extent of the wobble would be .0005 arc seconds, which corresponds to only a few angstrom units as viewed from a distance of 15 inches. This would be roughly similar to measuring the displacement of atoms in a sheet of paper due to thermally induced vibrations. The current accuracy of astrometry is around .02 to .03 arc seconds. In a single observation, but by observing the same star on many nights during a year, the accuracy can be increased to .005 arc seconds. This is still 10 times too insensitive to detect the wobble in the sun caused by Jupiter

when measured at a distance of 33 light years.

It is hoped that the accuracy of such observations will be refined by using photoelectric detectors instead of photographic plates. Currently, a technique called single aperture interferometry is being developed.

Dr. Black concludes that none of the existing or currently planned space systems have the capability to mount a meaningful search for other planetary systems. He is saying that, as far as this particular type of detection is concerned, the proposed space telescope will not be superior to a ground based system. A special purpose space telescope will be required. In the meantime, the existence of other planetary systems will depend on guesswork and inferences resulting from generalizations.

Several fields of investigation have converged to produce the present thinking about life elsewhere in the Universe. The first step was new ideas about the formation of stars. They are now believed to be formed by condensation from what is called "a whirling lens of gas and dust". According to this theory, planets are formed in the same process. Planetary systems are now believed to exist around a substantial fraction of stars. As yet, no planets have actually been detected outside of the solar system. Nevertheless, astronomers have no difficulty in accepting the idea that planetary systems are common throughout the universe.

The next develop is that of theories concerning the origin of life. Life on earth is believed to have come into existence as a result of some form of condensation of the so-called building blocks of biological molecules. These building blocks are amino acids, purines, pyrimidines and other small organic molecules that are produced by the action of ultra-violet light and other forms of radiation upon ammonia, carbon dioxide, hydrogen cyanide, methane, hydrogen and other small molecules that were thought to be present in the primitive reducing atmosphere.

The next concept comes from present knowledge of evolution, especially molecular evolution. Complex organisms evolve from small ones, in a continuous process that takes billions of years. Finally, on earth, mammals appeared, and then primates, anthropoids and human beings. Intelligent life is seen as a product of the Darwinian process of natural selection.

The next development is one that is perhaps less familiar. This is the fantastic develop of technology in radio astronomy, in data processing, in computers, and in detecting equipment so that now existing radio telescopes are capable of receiving signals from thousands of light years away. We may search for messages from our distant neighbors without undertaking excessive expenditures.

The expenditures of public funds on the search for extraterrestrial intelligence is an obvious target for criticism and budget cutting. In general, money spent on basic science is the first to disappear when economies are put into effect. This is true in industry and in government. Scientists are infinitely ingenious at bootlegging basic research by concealing it as part of their activities in applied science, or by alleging that the results will have a usefulness without being able to substantiate such a claim, such as saying that working on DNA might lead to a cure for cancer. Optimism is often used to persuade sources of funding that financial support be given to science. This may sound like callous and cynical deception, but it is rationalized and justified among scientists by the fact that if research is not supported, it will not be possible for knowledge to increase, and technological progress will soon stop.

Lord Kelvin said in 1858:

"Oersted would never have made his great discovery of the action of galvanic currents on magnets had he stopped in his researches to consider in what manner they could possibly be turned to practical account; and so we should not now be able to boast of the wonders done by the electric telegraph. Indeed, no great law in Natural Philosophy has ever been discovered for its practical applications, but the instances are innumerable of investigations apparently quite useless in this narrow sense of the word which have led to the most valuable results."

This guiding principle is still valid.

Nevertheless, if scientists sometimes exaggerate and offer hopes so as to win public support, there is one matter on which they must be uncompromisingly severe, and that is the maintenance of completely objective standards in the actual execution of experimental work. This point has been developed by Monod in "Chance and Necessity". He says that it took "many thousands of years for the kingdom of ideas to be invaded by the one according to which objective knowledge is the only authentic source of truth." This idea, says Monod, "wrote an end to the ancient animist covenant between man and nature, leaving nothing

in place of that precious bond but an anxious quest in a frozen universe of solitude. How could the idea of objectivity win acceptance?" asks Monod. He replies that it did not; it still has not, but it has commanded recognition by its performance.

It is the ideal of complete objectivity that demands ruthless criticism of scientific proposals. With this in mind, the search for extra terrestrial life has been strongly condemned by a physicist, H.P. Yockey. He reserves his most biting criticism for those who postulate the steps by which life could have arisen from non-living matter. Yockey quotes Cairns Smith as saying "We might say that the very first organism was the primitive earth itself that primitive organisms were initially viruses with the earth as the host". Yockey comments "*This is delightfully reminiscent of the Earth mother goddess in classical mythology and in primitive religions.*"

Yockey points out that science and religion have different and opposite belief systems. Doubt is a virtue in science and many well established theories have been replaced because of small discrepancies. On the other hand, faith is the important thing in religion. "A true believer confronted with evidence contrary to his doctrine merely regards this as a test of the steadfastness of his faith. The more his doctrine is denied by experience and observation the more tenatiously he clings to his holy faith. His greatest fear is heresy and treason to his doctrines." (Yockey)

The search for extraterrestrial intelligence shows some signs of being a religion. One of the articles of faith is that each star of suitable size for maintaining a planetary system capable of supporting life has such a planetary system. In short, there is a probability of one for suitable stars having planetary systems. This was based upon van de Kamp's observations, that were shown to be the result of inaccurate measurements as discussed above. One might expect that this would revise the deductions about the percentage of stars that are accompanied by planets. I see no sign of any such revision. Apparently, the accident with the telescope is regarded as a test of steadfast-

According to some critics, the search for extraterrestrial intelligence is an attempt to apply advanced technology in a context that has no scientific justification. Those who are interested in the search are accused of spending time and money on an effort that is not founded on facts. One critic has said *"that since the search for extraterrestrial life is based entirely on faith, it must be regarded as an exercise of religious belief."*

In the sixteenth century, Thomas Digges, an Englishman, proposed that the stars lie at differing distances in infinite three-dimensional space. The Italian philosopher Giordano Bruno supposed that the stars were other suns, circled by planets that were inhabited by people. For these heresies, Bruno was burned to death at the stake by the Inquisition in 1600.

Perhaps it is not accidental that the foreword to NASA's publication "The Search For Extra Terrestrial Intelligence" was written by Father Theodore Hesburgh. He says *"we should not be predisposed to accept a proposition that we indeed are alone and unique as creatures possessing intelligence and freedom in this whole vast universe".*

He is astute enough to call attention to the parallel between the Big Bang, and the statement "Let There Be Light" attributed to God. Father Hesburgh says *"As a theologian I would say that this proposed search for extraterrestrial intelligence is also a search of knowing and understanding God through his works -- especially those works that most reflect Him".*

Many scientists are devoutly religious, but there is a basic difference between beliefs in science and religion. Scientific beliefs are based on theories that are under constant attack, indeed, criticism and destruction of theories is essential to the integrity of science. A scientist who proposes a new theory expects it to be mercilessly attacked by his or her peers. The scientist may even attack his own theory when new findings come to light. By so doing, he will gain stature. This does not mean that foolish ideas should be put forward in an irresponsible manner. Many well established theories, such as the indivisibility of atoms, have been replaced because of small discrepancies resulting from careful experimental observation. Doubt is a virtue in science. I was fortunate enough to have been given the name Thomas, which supplied me with a role model.

In contrast to the situation in science, faith is essential to religion. The true believer does not need to understand, only to have faith. Furthermore, a true believer must disregard evidence that is contrary to his doctrine. His rejection of this evidence shows that he can pass a test of the strength of his belief. My role model, Thomas Didymus, got into trouble by demanding to be shown the evidence of a miraculous event that had been reported to him. As the hymn says:

"When Thomas first the tidings heard
how they had seen the risen Lord
He doubted the disciples word"

For this, Thomas was properly admonished.
He may have permanently fallen from grace, for, as the hymn says:

"How blest are they who have not seen
But yet whose faith has constant been
For they eternal life shall win".

To illustrate the conflict between faith and scientific evidence, I shall give the example of the debate surrounding the proposal that a sample of soil be returned from the surface of Mars, just as rocks were brought back from

the moon. We were confronted by those who believe that life existed on Mars in a form that could have catastrophic consequences if it were brought back to earth, such as the "Andromeda Strain" of science fiction. We found that people holding this belief were impervious to scientific argument. They alleged that organisms that could live on the inhospitable surface of Mars would be so hungry for the comfortable surroundings on the earth that they would run like wild fire and destroy us all. Our counter argument was that, if this were the case, then it should be even more dangerous to bring back a sample of soil from the Antarctic, because the chances were that Antarctic organisms would be much more likely to survive elsewhere on the earth than would be the case with a Martian organism that would be quite unaccustomed to a terrestrial environment. These arguments were in vain. There were actually suggestions that the sample of Martian soil be intercepted by a spacecraft orbiting the earth, in which scientist astronauts would test the sample to see if it contained the green plague. We were able to head off this fantasy by pointing out that the astronauts would have to commit suicide to prevent them from carrying back the deadly strain to the earth in a form that had not yet become perceptible.

Then came the test of faith. No life was detected by the elaborate chemical and biological testing equipment carried by the Viking expedition. Surely, we thought, the objections to Mars' surface sample return, would now be withdrawn. However, this has not been the case. All that has happened is that the cost, together with other priorities, has put Mars surface sample return so far into the future that the debate has mercifully been postponed.

A major consideration in postulating the existence of extraterrestrial intelligence is the estimation of how many earthlike planets might exist in the universe. These estimates are multifactorial, meaning that we first estimate the number of stars that might be surrounded by planetary systems, then we estimate how many of such planetary systems might contain an earth - like planet, followed by the percentage of earthlike planets that might develop complex forms of life, and the fraction of these in which complex life forms would develop intelligent life. Some authors are buoyantly optimistic. For example, Ronald Smith says that the fraction of planetary systems with potentially life supporting planets approaches 100%, or unity, and the fraction of these that possess intelligent life forms also approaches 100%.

One of the greatest uncertainties in such estimations is that of the lifetime of technical societies. According to some guesses, the lifetime is about 50 years. This is based on the fact that our own society has reached the capability of interstellar communication by radio transmission and reception, starting about 20 years ago. A pessimistic guess, based partly on recent events in the Moslem world and in Afghanistan, is that we have about 30 more years to go.

On the other hand, it is argued that other civilizations on other planets may have passed through a crisis such as we are enduring, and reached a steady state that could last for millions of years.

There are some authors who take a viewpoint at the opposite extreme . Some of them, such as Monod, are inclined to the viewpoint that intelligent life is a unique event that has occurred only on the Earth.

Other authors, such as William Pollard, and George Simpson, are inclined to the viewpoint that theories of intelligent life in other worlds are essentially based on wishful thinking. For example, Pollard says "*there is a deeply ingrained conviction in the great majority of mankind, to which the appeal of science fiction and fantasy bears witness, that the universe is so constituted that if*

an opportunity exists for life to originate, this will happen, and if an opportunity exists for hominids to evolve, this too will happen". Pollard says *" whatever may be the basis for such convictions, it must clearly be sought outside the domain of science".*

I conclude that a great deal of thinking in this field depends on the temperament of the author.

George Simpson, the well known paleontologist and evolutionist wrote an article in 1964 that is still widely quoted. His thesis was that we can learn more about life from terrestrial forms than we can from hypothetical extra-terrestrial forms. One of Simpson's main points was that those who speculated on the existence of extraterrestrial life often seemed to conclude that the absence of any evidence whatever enables them to make speculations that are not based on anything resembling facts. He quotes a "leading biologist" who wrote in 1962 *"we do not really know what the atmosphere of Venus is like, and we are therefore not severely limited in our conclusions."*

Eighteen years later, after it had been conclusively shown that life was impossible on Venus, Yockey points out that true believers cling to the idea that life did once exist there but was killed by a runaway greenhouse effect.

Astronomers who speculate on the existence of life elsewhere are apt to be much more stringent about their astronomical calculations than they are about biology. In contrast, Simpson is more tolerant of astronomical possibilities than he is of speculations concerning the development of intelligent life. He is quite willing to admit that earthlike planets probably exist. He points out that the number of stars in the portion of the universe that is discernible by light or by radio telescopes, is so incredibly enormous that even if the chances of any one of them having an earthlike planet were exceedingly small, the probability that some of them do would be considerable. He concludes that conditions that enable life to originate on the Earth may have existed also outside the solar system. Simpson then proceeds to discuss the origin of

life on Earth, and he says that virtually all biochemists agree that life on earth arose spontaneously from nonliving matter and that it would almost inevitably arise on sufficiently similar young planets elsewhere.

He then turns to a discussion of his own field of interest, paleobiology and, given the known fact that life originated, and evolved to the point of intelligent organisms on earth, how can we decide whether it is inevitable, probable, improbable or impossible for life elsewhere to have followed a similar or identical path ? He says that the fossil record shows very clearly that there is no central line leading steadily to the human species, but instead life has followed a continual and extremely intricate branching, in which process the vast majority of earlier forms of life have become extinct. Dinosaurs will never reappear. This is because they came into being through long chains of non-repetitive circumstances, and the existence of the human species depends on a very precise sequence of causes of events through two billion years or more. The chance that this will happen again on another planet he says is vanishingly small, even if there are millions or billions of possible planetary abodes of life. History does not repeat itself.

But even if humanoids existed elsewhere, would they send us a message or actually visit the earth? The distances are so vast that it would take years, or, more, than likely generations to send a message and receive a reply. Under these conditions says Simpson, the establishment of useful, intelligent intercommunication would be impossible. Simpson says he reaches these conclusions with regret, and he himself would like to be proved wrong. He ends his discourse with a plea that more money be spent in studying the systematics and evolution of earthly organisms. I have to point out that in the 16 years since Simpson's article has appeared, this expenditure of time and money has taken place increasingly and the funds for it have to a considerable extent been provided by grants from the space agency.

Another approach is used by Pollard, and actually his idea was published

previously elsewhere. This is based on the study on continental drift. Terrestrial life appeared four hundred million years ago and evolved on the single continental land mass for about 200 million years. This early continent was called Pangaea. At the end of this period, a large portion of the early continent called Gondwanaland broke off to the South, following which, 180 million years ago, Australia and Antarctica broke off from Gondwana and pursued an independent course of evolution. Australia became inhabited by marsupial animals, and no sign of a development leading to the appearance of human beings or humanoids took place. Finally, Australia was invaded by human beings about 50,000 years ago.

Another land mass separated about 130 million years ago. This was South America. The New World monkeys, which developed in this isolated continent did not develop into a line of apes that would eventually lead to human beings. Pollard's conclusion is that mammals have evolved in three locations on our Earth, and in only one of the three did the pathway lead to intelligent life. His point is that we cannot assume that intelligent life would appear on another planet. And in any case, we cannot calculate this possibility.

Many imaginative proposals have been made for the possibility of life in worlds elsewhere in the universe, based on an entirely different system of biochemistry from that of terrestrial life. For various reasons, interest in these contributions to science fiction seems to have dwindled. First of all, the more we know about the complexity of life, the more impossible it seems that any biochemical system except that of DNA and proteins, could provide the necessary biological chemistry for growth, maintenance, reproduction, and evolution. We know which elements exist in the universe, and we know a great deal about their chemical properties. Amino acids, the building blocks of proteins, have been found to exist in meteorites that reached the earth from outer space, the so-called carbonaceous chondrites. We conclude from this that amino acids can be formed from non-living matter anywhere in the universe where the raw materials are available. It is often theorized that these substances participated in the origin of life.

Before chlorophyll came into being, we think that the earth was inhabited by microorganisms that live in the absence of oxygen. These are called anaerobes. Such organisms live today in places such as the deep mud of rivers and lakes. Some of them cause diseases such as lockjaw and gas gangrene. They are killed by oxygen, and people with deep wounds that are infected with these organisms are sometimes placed in oxygen chambers to kill the gas gangrene organisms. A study of their biochemistry shows that they are related only very remotely to other life such as animals, plants, yeast and aerobic bacteria. They are the oldest "living fossils". We are studying a group of these called archaebacteria. One type produces methane or "marsh gas", so called because these bacteria make the gas in the mud of swamps, and it bubbles to the surface. It may burn at night, giving rise to the fable of Will O' The Wisp.

These primitive organisms use the same genetic system and make proteins in the same way that we do. We assume that they and we are descended from the same common ancestor, an early microorganism that used the same genetic code that is employed by all living organisms on the earth.

This has taken us back in history to about 3 billion years ago. In still earlier periods, geological and chemical evolution prepared the earth for the appearance of life. Each gigantic step in this long chain of events was needed for the eventual emergence of complex living organisms such as flowering plants and vertebrate animals. We can easily realize that human beings could not have appeared until nature first invented monkeys. However, it is equally true that animals would never have come into existence unless they had been preceded by bacteria. Indeed, every cell in our bodies contains a large number of small particles called mitochondria. These are necessary for our existence. They are the descendents of bacteria that infected cells 2 billion years ago. These bacteria came to dinner, and stayed there. Now we are dependent on them for our own lives. Each mitochondrion has its own piece of DNA. Apparently, mitochondria travel from generation to generation only by means of the female sex cell, the ovum.

The idea that living organisms could appear by spontaneous generation was accepted for many centuries. So far as I can tell, the idea did not come into conflict with the account of special creation as outlined in the Book of Genesis. It was popularly thought that putrefying meat gave rise spontaneously to maggots that turned into flies. This legend was destroyed by experiments carried out by Redi. His classically simple experiment is an example of the power of observation and deductive reasoning. He allowed meat to putrefy in a vessel that was exposed to the air, but the entrance to which was closed by a piece of cheese cloth. A control sample was exposed without the cheesecloth. In those days, there was no lack of flies. Nevertheless, maggots did not appear when the meat was protected by cheesecloth.

However, the protected meat putrefied. The explanation for this had to await the arrival of Louis Pasteur. He showed that putrefaction was caused by another type of living organism, bacteria. Pasteur then proceeded to deal the final death blow to the theory of spontaneous generation. He showed that meat broth remained fresh and unspoiled after boiling if dust were kept from contact with it. This, of course, is why test tubes of culture medium are plugged with cotton. There remained the matter of where life came from in the first place. This was discussed in a famous quotation by Charles Darwin:

"It is often said that all of the conditions for the first production of a living organism are now present, which could ever have been present. But if (And oh, what a big if!) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc. present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed".

I should devote some time to discussing the accumulation of evidence that has gone into the conclusion that emergence of intelligent life on the earth took between four and five billion years.

The evidence is of two general kinds, fossil and molecular. The dating of fossils is based on geological conclusions, and also on analyses for isotopes that are known to decay at definite rates. These findings give us milestones or bench marks for conclusions that are drawn from the sequences of protein molecules and DNA molecules. The general principle involved is the so-called evolutionary clock that was first discovered in the molecules of hemoglobins. Each hemoglobin molecule, in all vertebrate animals extending over the series from sharks to our own species contains strings of amino acids joined together in a sequence that is characteristic for the species. The number of different amino acids is 287, contained in two sequences of approximately equal length. The sequences of amino acids in about 100 different hemoglobin molecules have been measured, and each sequence is different, significantly with a few conspicuous exceptions. The hemoglobins of human beings and chimpanzees are identical.

The percentage differences between the sequences of hemoglobin molecules steadily increase as one goes from placental mammals to marsupials, then to the duckbill platypus, followed by the chicken, next to viper, then frogs and newts, next the bony fishes such as the carp, and finally a primitive cartilaginous fish, a shark of the sea coast of Australia. Moreover, the difference between shark hemoglobin and carp hemoglobin is just as great as the difference between shark hemoglobin and human hemoglobin. In short, the divergence of hemoglobins of the world of vertebrates mimicks the classification used in zoology textbooks.

The rate of change in hemoglobin is measured by studying the fossil record which shows the length of time that various families of vertebrates have been on earth. We calculate that one amino acid replacement takes place in hemoglobin every 5 million years. This takes us back to the origin of fishes about 500 million years ago. We go back even further by examining proteins that are

found in microorganisms as well as in animals. These help fill in the record where there are no known fossils. Finally, we come to the earliest fossils, which are those of blue-green algae found in precambrian rocks. Blue-green algae are still common today. Their name tells us that they contain chlorophyll. Therefore, they could not have appeared until the atmosphere of the earth contained oxygen, because oxygen is produced during photosynthesis, in which chlorophyll reacts with carbon dioxide and water. The early atmosphere, before the appearance of life, is thought to have contained very little oxygen. It was a "nonoxidizing atmosphere", probably consisting of CH_4 (methane), NH_3 (ammonia) free hydrogen, and water. There was no ozone layer, and hence ultraviolet light reached the Earth's surface at a high intensity. It is thought that ultraviolet light acted on the atmospheric components to produce small molecules, including amino acids and also nitrogenous bases of the type found in nucleic acids, RNA and DNA. Lightning and, to a lesser extent, volcanic action aided in this synthetic process. The small molecules became dissolved in the oceans and other bodies of water to form a "primitive soup". When the first organisms eventually appeared, they used the "primitive soup" as a source of food. Eventually the food supply was used up, and a new method of producing food came into being. This was photosynthesis, and from this came the present atmosphere containing 21% oxygen, and, with it, the ozone layer.

Much effort is being spent by scientists on the origin of life and on early evolution, both in carrying out model experiments, and in examining various theories. As we have seen, there is a great desire by some scientists to obtain evidence of intelligent life in other worlds. All these activities add to the store of human knowledge, and this is ample justification for supporting them and participating in them.

I also feel, however, that the rapid increase in our understanding of biological evolution forces us to consider an even more basic question which is " What is the meaning of life"?

Living organisms use or trap energy that they obtain from external sources, primarily from sunlight, and they use the energy for their own purposes. The most essential of these purposes is reproduction, which enables life to continue.

Onsager and Morowitz have defined life as follows:

"Life is that property of matter that results in the coupled cycling of bioelements in aqueous solution, ultimately driven by radiant energy to attain maximum complexity."

The bioelements are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. The term "coupled cycles" means that biological compounds undergo chemical cycles that are joined to each other. For example, inorganic phosphate becomes adenosine triphosphate by the action of sunlight on chloroplasts. The adenosine triphosphate,ATP, supplies energy to other biological reactions, and becomes inorganic phosphate again. Mineral elements, such as calcium, magnesium and iron, also participate in life.

Maximum complexity is the result of biological evolution. Single cell organisms become multi-celled organisms, and these become increasingly large and complex. However, this attempt at a definition of life has brought us no closer to the meaning of life than we were before. The rich diversity of organisms on the Earth has taken billions of years to develop. Was this process undertaken for the glory of God?

On the other hand, can we be conceited enough to believe that these aeons of evolution were for the sole purpose of producing human beings? If we believe this, then what are human beings intended for? Obviously, they excel at reproducing and extending their influence over most other forms of life. It is also evident that human beings may be too clever for their own good.

Perhaps an important purpose for our existence is that we should try to communicate with intelligent life elsewhere in the universe. Actually, this isn't such a bad idea. It gives us something to do in addition to making things comfortable for ourselves, which, after all, seems to be what all organisms do. Perhaps it is intended that human beings should go a bit beyond the function of self gratification, including the feelings of satisfaction that come from deeds of altruism.

It goes without saying that we should love our neighbors, perform good works, clean up the environment, strive for world peace, and preserve our spaceship Earth. The future of the world is in the hands of our species.

However, even if we have the egotism to conclude that we have a special destiny, what about the purpose of all the other living organisms, more than a million different species, that have found their way into every conceivable ecological niche? What about all their ancestors through several billion years, millions of which ancestors became extinct?

Sometimes biochemistry tells us more than metaphysics when we investigate life. We have learned a great deal about the chemistry of life in recent years. There is one biochemical substance that is carried over from generation to generation, in what the geneticists used to call the "continuity of chromatin". This substance is DNA. Without DNA, life would vanish from the earth in a fairly small number of years. The strategy of life must be the protection of DNA. Life has to be tailored to fit the biochemical properties of DNA, and we know something about these properties. DNA resists change, which means that "like produces like", but DNA also permits change, which means that evolution takes place.

One property of DNA is that it replicates, meaning that tow identical copies of a DNA molecule are produced by separation of its two strands, and assembly of two "daughter strands" that are identical with their two complementary counterparts. This takes place every time that a cell divides to produce two new cells. The next property is that DNA undergoes mutations, in which one nucleotide is replaced by another. A second form of mutation is deletion or insertion of short pieces of DNA within a strand.

The third property of DNA is duplication, which is different from replication in that two identical pieces of DNA are joined end to end. In this way, an organism can acquire two genes for the same function. One of the genes continues to have its original function, and the second, duplicate gene becomes changed by mutations so that it may take on a new function, or, it may be withdrawn from use. The three properties of DNA, like the Fates, sit in judgement on life to spin the thread of life, and cut it off.

Duplication increases the chances that a DNA molecule may survive. Living organisms are the protective shield for DNA. All successful evolution is directed towards the objective of preventing DNA molecules from becoming extinct. When we understand this, we begin to understand the meaning of life.

The prospects for the remote future of the universe are being debated by cosmologists. The red shift, caused by the Doppler effect, shows that all the galaxies are receding from each other. The rate of separation depends on distance. Galaxies that are 20 million light years away are receding at a rate of about 340 kilometers per second. The expansion is the same in all directions.

The unsettled question is "Will the expansion continue forever or will the receding galaxies stop some day and then reverse their motion, eventually coming together again in a collapse?" Most astronomers seem to conclude that the recession of distant galaxies, the average density of matter, the age of the chemical elements and the abundance of deuterium suggest that the expansion cannot be halted or reversed. If so, there won't be another "big bang" with the accompanying creation of light and matter.

In the meantime, we have heard nothing from our celestial neighbors. Their spacecrafts have not landed on the Earth, and their messages have not been picked up by our radiotelescopes. The stars glitter soundlessly at night just as they did when Joseph Addison wrote his poem.

The spacious firmament on high
With all the blue ethereal sky,
And spangled heavens, a shining frame
Their great Original proclaim.
The unwearied sun from day to day,
Doth his Creator's power display,
And publishes to every land,
The work of an almighty Hand.
Soon, as the evening shades prevail,
The moon takes up the wondrous tale
And nightly to the listening earth,
Repeats the story of her birth
While all the stars that round her burn
And all the planets in their turn
Confirm the tidings as they roll
And spread the truth from pole to pole.
What though in solemn silence all
Move round the dark terrestrial ball?
What though no real voice nor sound,
Amid their radiant orbs be found?
In reason's ear they all rejoice,
And utter forth a glorious voice
For ever singing as they shine
"The hand that made us is divine."