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IS THERE LIFE ON THE OTHER WORLDS?[1]

By Sir JAMES JEANS

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So long as the earth was believed to be the center of the universe the question of life on other worlds could hardly arise; there were no other worlds in the astronomical sense, although a heaven above and a hell beneath might form adjuncts to this world. The cosmology of the *Divina Commedia* is typical of its period. In 1440 we find Nicholas of Cusa comparing our earth, as Pythagoras had done before him, to the other stars, although without expressing any opinion as to whether these other stars were inhabited or not. At the end of the next century Giordano Bruno wrote that "there are endless particular worlds similar to this of the earth." He plainly supposed these other worlds—"the moon, planets and other stars, which are infinite in number"—to be inhabited, since he regarded their creation as evidence of the Divine goodness. He was burned at the stake in 1600; had he lived only ten years longer, his convictions would have been strengthened by Galileo's discovery of mountains and supposed seas on the moon.

The arguments of Kepler and Newton led to a general recognition that the stars were not other worlds like our earth but other suns like our sun. When once this was accepted it became natural to imagine that they also were surrounded by planets and to picture each sun as showering life-sustaining light and heat on inhabitants more or less like ourselves. In 1829 a New York newspaper scored a great journalistic hit by giving a vivid, but wholly fictitious, account of the activities of the inhabitants of the moon as seen

[1] Afternoon lecture, Royal Institution of Great Britain, November 20, 1941.

through the telescope recently erected by His Majesty's Government at the Cape.

It will be a long time before we could see what the New York paper claimed to see on the moon—bat-like men flying through the air and inhabiting houses in trees—even if it were there to see. To see an object of human size on the moon in detail we should need a telescope of from 10,000 to a 100,000 inches aperature, and even then we should have to wait years, or more probably centuries, before the air was still and clear enough for us to see details of human size.

To detect general evidence of life on even the nearest of the planets would demand far larger telescopes than anything at present in existence, unless this evidence occupied an appreciable fraction of the planet's surface. The French astronomer Flammarion once suggested that if chains of light were placed on the Sahara on a sufficiently generous scale, they might be visible to Martian astronomers if any such there be. If this light were placed so as to form a mathematical pattern, intelligent Martians might conjecture that there was intelligent life on earth. Flammarion thought that the lights might suitably be arranged to illustrate the theorem of Phythagoras (Euclid, I. 47). Possibly a better scheme would be a group of searchlights which could emit successive flashes to represent a series of numbers. If, for instance, the numbers 3, 5, 7, 11, 13, 17, 19, 23 . . . (the sequence of primes) were transmitted, the Martians might surely infer the existence of intelligent Tellurians. But any visual communication between planets would need a combination of high telescopic power at one end and of engineering works on a colossal, although not impossible, scale at the other.

Some astronomers—mainly in the past—have thought that the so-called "canals" on Mars provide evidence of just this kind, although of course unintentionally on the part of the Martians. Two white patches which surround the two poles of Mars are observed to increase and decrease with the seasons, like our terrestrial polar ice. Over the surface of Mars some astronomers have claimed to see a geometrical network of straight lines, which they have interpreted as an irrigation system of canals, designed to bring melted ice from these polar caps to parched equatorial regions. Percival Lowell calculated that this could be done by a pumping system of 4,000 times the power of Niagara. It is fairly certain now that the polar caps are not of ice, but even if they were, the radiation of the summer sun on Mars is so feeble that it could not melt more than a very thin layer of ice before the winter cold came to freeze it solid again. Actually the caps are observed to change very rapidly and are most probably clouds consisting of some kind of solid particles.

The alleged canals can not be seen at all in the largest telescopes nor can they be photographed, but there are technical reasons why neither of these considerations is conclusive against the existence of the canals. A variety of evidence suggests, however, that the canals are mere subjective illusions—the result of overstraining the eyes in trying to see every detail of a never very brightly illuminated surface. Experiments with school-children have shown that under such circumstances the strained eye tends to connect patches of color by straight lines. This will at least explain why various astronomers have claimed to see straight lines not only on Mars, where it is just conceivable that there might be canals, but also on Mercury and the largest satellite of Jupiter, where it seems beyond the bounds of possibility that canals could have been constructed, as well as on Venus, on which real canals could not possibly be seen since its solid surface is entirely hidden under clouds. It may be significant that E. E. Barnard, perhaps the most skilled observer that astronomy has ever known, was never able to see the canals at all, although he studied Mars for years through the largest telescopes.

A more promising line of approach to our problem is to examine which, if any, of the planets is physically suitable for life. But we are at once confronted with the difficulty that we do not know what precise conditions are necessary for life. A human being transferred to the surface of any one of the planets or of their satellites, would die at once and this for several different reasons on each. On Jupiter he would be simultaneously frozen, asphyxiated and poisoned, as well as doubly pressed to death by his own weight and by an atmospheric pressure of about a million terrestrial atmospheres. On Mercury he would be burned to death by the sun's heat, killed by its ultra-violet radiation, asphyxiated from want of oxygen and desiccated from want of water. But this does not touch the question of whether other planets may not have developed species of life suited to their own physical conditions. When we think of the vast variety of conditions under which terrestrial life exists on earth—plankton, soil-bacteria, stone-bacteria and the great variety of bacteria which are parasitic on the higher forms of life, it would seem rash to suggest that there are any physical conditions whatever to which life can not adapt itself. Yet, as the physical states of other planets are so different from that of our own, it seems safe to say that any life there may be on any of them must be very different from the life on earth.

The visible surface of Jupiter has a temperature of about $-138°$ C., which represents about 248 degrees of frost on the Fahrenheit scale. The planet probably comprises an inner core of rock, with a surrounding layer of ice some 16,000 miles in thickness, and an

atmosphere which again is several thousands of miles thick and exerts the pressure of a million terrestrial atmospheres which we have already mentioned. The only known constituents of this atmosphere are the poisonous gases methane and ammonia. It is certainly hard to imagine such a planet providing a home for life of any kind whatever. The planets Saturn, Uranus, Neptune and Pluto, being further from the sun, are almost certainly even colder than Jupiter and in all probability suffer from at least equal disabilities as abodes of life.

Turning sunwards from these dismal planets, we come first to Mars, where we find conditions much more like those of our own planet. The average temperature is about $-40°$ C., which is also $-40°$ on the Fahrenheit scale, but the temperature rises above the freezing point on summer afternoons in the equatorial regions. The atmosphere contains at most only small amounts of oxygen and carbon dioxide, perhaps none at all, so that there can be no vegetation comparable with that of the earth. The surface, in so far as it can be tested by a study of its powers of reflection and polarization, appears to consist of lava and volcanic ash. To us it may not seem a promising or comfortable home for life, but life of some kind or other may be there nevertheless.

Being at the same average distance from the sun as the earth, the moon has about the same average temperature, but the variations around this average temperature are enormous, the equatorial temperature varying roughly from 120° C. to $-80°$ C. The telescope shows high ranges of mountains, apparently volcanic, interspersed with flat plains of volcanic ash. The moon has no atmosphere and consequently no water; it shows no signs of life or change of any kind, unless perhaps for rare falls of rock such as might result from the impact of meteors falling in from outer space. A small town on the moon, perhaps even a large building, ought to be visible in our largest telescopes, but, needless to say, we see nothing of the kind.

Venus, the planet next to the earth, presents an interesting problem. It is similar to the earth in size but being nearer the sun is somewhat warmer. As it is blanketed in cloud we can only guess as to the nature of its surface. But its atmosphere can be studied and is found to contain little or no oxygen, so that the planet's surface can hardly be covered with vegetation as the surface of the earth is. Indeed, its surface is probably so hot that water would boil away. Yet no trace of water-vapor is found in the atmosphere, so that the planet may well be devoid of water. There are reasons for thinking that its shroud of clouds may consist of solid particles, possibly hydrates of formaldehyde. Clearly any life that this planet may harbor must be very different from that of the earth.

The only planet that remains is Mercury. This always turns the same face to the sun and its temperature ranges from about 420° C. at the center of this face to unimaginable depths of cold in the eternal night of the face which never sees the sun. The planet is too feeble gravitationally to retain much of an atmosphere and its surface, in so far as this can be tested, appears to consist mainly of volcanic ash like the moon and Mars. Once again we have a planet which does not appear promising as an abode of life and any life that there may be must be very different from our own.

Thus our survey of the solar system forces us to the conclusion that it contains no place other than our earth which is at all suitable for life at all resembling that existing on earth. The other planets are ruled out largely by unsuitable temperatures. It used to be thought that Mars might have had a temperature more suited to life in some past epoch when the sun's radiation was more energetic than it now is, and that similarly Venus can perhaps look forward to a more temperate climate in some future age. But these possibilities hardly accord with modern views of stellar evolution. The sun is now thought to be a comparatively unchanging structure, which has radiated much as now through the greater part of its past life and will continue to do the same until it changes cataclysmically into a minute "white-dwarf" star. When this happens there will be a fall of temperature too rapid for life to survive anywhere in the solar system and too great for new life ever to get a foothold. As regards suitability for life, the earth seems permanently to hold a unique position among the bodies surrounding our sun.

Our sun is, however, only one of myriads of stars in space. Our own galaxy alone contains about 100,000 million stars, and there are perhaps 10,000 million similar galaxies in space. Stars are about as numerous in space as grains of sand in the Sahara. What can we say about the possibilities of life on planets surrounding these other suns?

We want first to know whether these planets exist. Observational astronomy can tell us nothing; if every star in the sky were surrounded by a planetary system like that of our sun, no telescope on earth could reveal a single one of these planets. Theory can tell us a little more. While there is some doubt as to the exact manner in which the sun acquired its family of planets, all modern theories are at one in supposing that it was the result of the close approach of another star. Other stars in the sky must also experience similar approaches, although calculation shows that such events

must be excessively rare. Under conditions like those which now prevail in the neighborhood of the sun, a star will only experience an approach close enough to generate planets about once in every million, million, million years. If we suppose the star to have lived under these conditions for about 2,000 million years, only one star in 500 million will have experienced the necessary close encounter, so that at most one star in 500 million will be surrounded by planets. This looks an absurdly minute fraction of the whole, yet when the whole consists of a thousand million million million stars, this minute fraction represents two million million stars. On this calculation, then, two million million stars must already be surrounded by planets and a new solar system is born every few hours. The calculation probably needs many adjustments; for instance, conditions near our sun are not at all typical of conditions throughout space and the conditions of to-day are probably not typical of conditions in past ages. But even so the calculation suggests, with a large margin to spare, that although planetary systems may be rare in space, their total number is far from insignificant. Out of the thousands or millions of millions of planets that there must surely be in space, a very great number must have physical conditions very similar to those prevailing on earth.

We can not even guess whether these are inhabited by life like our own or by life of any kind whatever. The same chemical atoms exist there as exist here and must have the same properties, so that it is likely that the same inorganic compounds have formed there as have formed here. If so, we would like to know how far the chain of life has progressed but present-day science can give no help. We can only wonder whether any life there may be elsewhere in the universe has succeeded in managing its affairs better than we have done in recent years.

THE MECHANISM OF SPECIES ADAPTATION TO CARCINOGENS

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INTRODUCTION

THAT the cancer cell is the result of a slow process of adjustment of normal cells to an unusual environment over a period of time embracing several or many cell-division cycles is the simple hypothetical basis upon which the experiments described herein were undertaken. The concept is not new, but as far as known, little if any experimental evidence has been produced in support of it. Therefore it was thought that some light might be thrown on the process of cancer induction by observing the behavior of small free-living organisms in the presence of carcinogenic agents over a considerable period of the racial history involving numerous successive generations.

We do not believe that the past experience of cancer investigators, either in the clinical or in the experimental fields, warrants the assumption that the genesis of a cancer cell involves a sudden change of a normal cell. All pathological entities barring those due to wounds and hereditary defects are the result of a process—a process of adjustment to an unusual or unfavorable environment. Cancer, we suspect, is no exception unless it be that the process here is slower than in most other diseases, and this slowness may be due in part to the fact that the genetic mechanism of the cell is primarily affected.

The clinically observed association of cancer with chronic irritation, the prolonged incubation period in experimentally induced cancer and the various precancerous lesions and stages that have been described, all seem to fit in with the concept of *gradualism* as a reasonable hypothesis in the genesis of cancer. The clinical examples of a step-like derivation of malignant growth does not exclude completely, of course, the alternative concept of a sudden mutational change as an occasional mechanism, for it is true that mutations can be induced experimentally with some of the same agents that are known to induce cancer and as the result of a single stimulus of great magnitude (x-rays, gamma rays of radium, heat). Such agents may either destroy one or more genes or disarrange the genic pattern and sequence. But in nature these highly artificial procedures are certainly the exceptions rather than the rule. It seems reasonable then to assume that a genetic change may be very frequently the culmination of a series of subliminal stimuli which have extended through many cell-divisions or generations.

The successful immunization of individual animals to multiple lethal doses of various toxins is well known, and can be achieved best by means of interval injections of increasing doses over a considerable