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ASTROBIOLOGY

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THE subject of astrobiology—the consideration of life in the universe elsewhere than on earth—is one that has been so often and so inadequately treated that the immediate and natural tendency of an experienced reader is to expect another bit of pseudo-scientific romancing.

The subject, nevertheless, is capable of serious and perhaps profitable consideration, even before an advance in astronomical instruments gives us observational answers to one part of our question. The problem before us in this Leaflet is to consider to what extent the universe is inhabitable by life as it exists on earth; to what extent, consistent with fundamental chemical similarity, the character of life elsewhere might be at variance with its character here; and whether the extra-terrestrial universe is, in fact, inhabited.

The Inhabitability of the Universe: If we could arrange an interstellar Noah's Ark to transport exemplars of all species to other parts of the universe, the problem of determining what destination would permit the survival of most of the cargo is one which the astronomer cannot altogether determine. The destination would have to enjoy conditions not too dissimilar to those enjoyed on earth. One of the important considerations is the chemical constitution, involving fairly high proportions of carbon, oxygen, nitrogen and hydrogen, together with smaller quantities of a large number of elements, and their existence in such proportions that the compounds found on earth could exist, particularly water. Other requirements include: a temperature like that on earth; a pressure at the surface not too dissimilar to conditions here; an atmospheric density, within moderate ranges, like that of earth; a source of light energy adequate to keep plants alive; and the absence of great variations in any of these factors.

The range of possible conditions will be quite different for different forms of life. Conditions adequate to permit human life or any high forms of life to exist would be much less frequently encountered than those sufficient to allow a continued existence of simpler plants and animals. Even on earth life has adapted itself to a wide variety of conditions, existing at the equator as well as in the polar regions, living under the tremendous pressures of the ocean floor as well as those of the higher peaks, adapting itself to light and shade, withstanding storms, and in some cases becoming adapted to a chemical environment such as iron or vinegar: doubtless some forms of life could persist in a still wider range of conditions throughout the universe.

The trend of modern investigation is to accept not merely the identity of chemical elements throughout the universe, but also their existence in approximately the same proportions as found on earth. A few exceptions only need be noted. An object much smaller than the earth would quickly lose molecules of lighter gaseous substances which might originally be present, so that there might come to be a deficiency of hydrogen, oxygen and nitrogen in such small bodies. At the other end of the range of size the huge masses of stars may be consuming their supplies of these same elements, as well as of carbon and the lighter metals, and any planetary system formed out of a white dwarf from the near approach or collision with another star might therefore be deficient in chemicals needed for life. For the rest, however, the problem of chemical constitution is one that is hardly apt to trouble the captain of our hypothetical interstellar ark.

Since water is necessary for life, we might put our temperature limits at zero to one hundred centigrade, although we may recognize that, when containing compounds in solution or suspension, water remains liquid slightly beyond these limits in both directions. In addition, we recognize that life is able to protect its own temperature, for warm-blooded animals will live indefinitely in temperatures well below the freezing point. To what extent life can protect itself from excessive heat is doubtful, chemical means of reducing temperature not being as readily available as means of increasing it.

The effect of pressure is probably not as important as it seems to us. Though variations in pressure distress human beings, they may become adapted in a short time; and we know that life exists at the bottom of the ocean where it is subjected to enormous pressures. There seems to be no reason why life could not adapt itself, granted a period for adaptation, to any pressures whatsoever.

Life is also able to adapt itself to considerable variation in most of its conditions, and it is doubtful whether a longer period of rotation of a planet would have any serious effect upon the existence of life. The same is probably true of the circularity of a planetary orbit, the inclination of the axis, and the constancy of radiation, all of which are mentioned by Shapley as among the necessary requirements for the existence of life.

It would seem possible for us, therefore, to restrict our first inquiry to the existence of planets throughout the universe having suitable temperatures, which factor will in general indicate as well the existence of radiant energy in a form and degree suitable for life. Upon the basis of this criterion it is not to be doubted that appropriate conditions exist elsewhere in the universe: even within the limits of our solar system there are several places which meet the minimum requirements. Mars comes immediately to mind, and Venus as well. Even Mercury is not altogether impossible as a habitation for the simpler forms of life—provided that oxygen has not been altogether lost—although such life could exist only in a limited zone between the extremely hot sunward side and the excessively cold farther side. All the outer planets and their satellites are out of the question because of their low temperature, while their small size rules out the asteroids and the satellites of the inner planets by depriving them of atmospheres.

Planetary systems may exist elsewhere: their frequency will determine, in large measure, the extent of the inhabitable universe, since we may suppose the solar system to be a fair representative of planetary systems elsewhere, and that there are, in general, a few inhabitable planets per planetary system. We do not know altogether how planetary systems arise; if produced through the contraction of an originally tenuous nebula, then planetary systems must be almost as common as stars in the universe. If produced by the fission of stars, there may be, perhaps, half as many. If, on the other hand, the solar system was produced by the near approach of two stars or by any similar exceptional condition, then planetary systems will be relatively rare. But in a galaxy containing approximately one hundred and fifty thousand millon stars, there must be at the lowest estimate a very large number of planetary systems, and in a universe containing many galaxies, a correspondingly greater number. There is no dearth of living quarters, then, in our universe.

The Characteristics of Life: The process of evolution depends upon the gradual accretion of relatively minute variations or mutations, and the occurrence of these evolutionary elements is recognized to be a matter of chance. Assuming, then, that life is identical in its first simple appearance in all parts of the universe, diversity would nevertheless ensue even under similar environmental conditions; and with diverse conditions acting as a spur, an inconceivable variety of living forms could develop. Within this great diversity there might be many cases of similarity superficially imposed upon a diverse background, just as on earth we find many cases of parallel development, such as sex dimorphism in plants and animals, central nervous systems in the social hymenoptera and in primates, wings in birds, mammals, fish, and insects, and so forth. But we cannot expect that any single multicellular organism would develop all or almost all of the traits which distinguish a given species on earth.

To what extent must all the chemicals necessary for the continuation of life be readily available in order that such life may exist? It is a fact worthy of attention that not all necessary elements need be common: life, once established, is quite capable of hunting for and obtaining the rarer elements needed for its own existence. The roots of a plant are organs capable of searching for water at great distances. Animals are especially adapted to seek and obtain vegetable food even where the latter is not easily attainable. Carnivorous animals are adapted for hunting their prey. An extra-terrestrial observer might well be pardoned for believing deserts unfitted for life based on water; yet we find that both animals and vegetables persist under these conditions. A still greater degree of adaptation is demonstrated by the ability of parasitic forms to find and occupy those organisms which are to them the only habitable environment.

So in another world a different quantitative distribution of chemicals might leave life possible even to organisms based on the carbon-oxygen-nitrogen-hydrogen compounds with which we are familiar. If nitrogen were rare instead of common and the other elements proportionately commoner, we might very well have organisms that obtain all other elements by a simple process of breathing or absorbing them from the environment, but which are especially adapted to the pursuit of nitrogen. Or, if oxygen were the rare element, we might have organisms that breathe CH_4 and N_2, and seek and eat silicates in order to obtain the oxygen content.

Life in the Universe: To say that the universe is inhabitable, or even to estimate the extent of its habitability, leaves untouched the problem of whether the universe actually contains life. This problem may be approached in four ways, three observational and one inferential, but none of them gives us, as yet, completely reliable information.

With present or future instruments it might be possible to observe life, or physical and chemical changes associated with life, on other planets. Observations of Mars are strongly suggestive of life, observations of the moon are definitely negative, and no other celestial objects have as yet had significant scrutiny. It might be possible to analyze meteorites and discover in them life that must have existed elsewhere than on earth. In 1933 Lipman did this, with positive results; but repetitions of the experiment by Roy, even when using parts of the same meteorite, did not support Lipman's conclusions. A third experimental possibility exists in interplanetary communication, which could give favorable results, of course, only if life elsewhere had attained a high degree of intelligence. Nothing at all has been accomplished along these lines.

With the probable exception of Mars, therefore, we are left entirely to an estimate of probabilities, which will depend very largely upon the method of origin of life. If, for example, life arises whenever its constituent chemicals form an appropriate system, then the frequency of life in the universe will depend, not merely upon inhabitability, but upon the accident of the appropriate chemical structure arising. It is quite possible that, whereas life, once formed, can adapt itself to a wide variety of environmental circumstances, its origin must come from a strictly limited coincidence of rather unusual conditions. If this were the case, there might be many places throughout the universe where life could exist but does not, due to the non-occurrence of the originating conditions. As we do not know what the conditions of origin are, we are unable to say how rare life may be, or even to affirm that life must exist elsewhere at all. On the other hand, if the conditions for the origin of life are sufficiently simple that they will inevitably occur whenever life may be supported, then every inhabitable part of the universe will be inhabited, and the absence of life rather than its presence may be the exception.

If life should be something other than a natural phenomenon; if, in fact, it should be produced by special creation, then the whole problem is relegated to the intentions of God, and the assumption may be made that so large a universe as ours would not be used merely for life on such an infinitesimal part of it as this earth.

A third solution remains. This is the assumption that life comes only from life and never arises either by evolution or emergence from the inanimate, or by special creation. This philosophy avoids the difficulties of origin, and it is possible to assume either that life existed eternally in the past along with an eternal physical universe, or that both had an origin, possibly by divine creation, at some specific era of past time. In any case the doctrine of Pan-Vitalism implies that life on earth must have arrived here from some other region, possibly being carried on meteorites formed by the destruction of another life-bearing planet. The whole universe may thus be filled with seeds of life which settle now and then on planetary bodies, and grow into life on those planets where conditions are favorable. Conditions in the universe would then be analogous to conditions on earth, where any particular area may for the moment support no vegetation, but where each area is constantly seeded by the wind, and, when conditions become favorable, burgeons with life and becomes in its turn a source of insemination for neighboring land.

Thus two of the three philosophical possibilities imply that life is not limited to the earth, while the third makes this same conclusion overwhelmingly likely. Add to this the slight observational evidences of life, and we may conclude, with a fair degree of assurance, that life in the universe is not confined to our planet.