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# Dynamics of Life in the Universe

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By John Hulley

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The preceding article (*Space Journal*, Summer, 1958) described human activity from an ecological aspect: seeking expansion and survival, humans may carry life from planet to planet. Illustrations were taken from nature as we observe it on Earth's surface. The next step is to examine the hypothesis from the point of view of nature as we observe it in the Universe around us. At this level, the interacting forces are simpler and more fundamental.

During most of recorded history, men have gazed upon the heavens with a mixture of wonder and foreboding. In the heavens they personified forces which could give, alter or remove life. These personifications represented a view of reality which approximated the truth. One important error, however, was the shortness of time-concepts; the end of the world has been anticipated on specific dates which turned out to be incorrect.

In recent centuries, the pendulum has swung the other way. The extreme view was adopted that the present order of things is eternal. The first telescopes revealed only stable revolutions in our planetary system. Discarding historical beliefs, early scientists substituted a relaxing view of invariable and perpetual motions in a calm Universe.

Today we have bigger telescopes, as well as spectroscopes and radiotelescopes, supplemented by increasing microscopic observations and a growing knowledge of Earth's history. The application of physical sciences takes us out of static analysis and introduces us to the dynamics of the Universe. In the words of C. Payne-Gaposchkin,

> Ten years ago in our hypotheses of cosmic evolution we were thinking in terms of gravitation and light pressure. . . . Tomorrow we may contemplate a galaxy that is essentially a gravitating, turbulent electromagnet.
>
> (*Scientific American*, September, 1953)

Modern astronomy is approaching a middle position between the extreme views of earlier times. We live in a cosmos, the forces of which can indeed create, change or remove life.

All bodies in the Universe—stars, comets, planets, asteroids, meteors, cosmic clouds and dust—are composed of the same atoms; all are radiant, but in different degrees. Stars represent the highest degree of atomic activity. Nuclear fusion occurs at temperatures ranging from thousands to millions of degrees. This process transforms an original supply of hydrogen into other types of atoms. In their formative stages, stars may cast off the aggregations of matter which form the lesser bodies of the Universe. While the degree of stellar radiation varies, it is always intense.

On smaller bodies, atomic activity is substantially below the level of nuclear fusion. On their surfaces, the relative coolness permits



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the stability of atomic structure. Under certain limited conditions, a planetary surface may support processes which cannot occur in the nuclear furnace of a star. With the right combination of atoms, with sufficient gravity to retain atmosphere, and under the stimulus of stellar radiation, complex transformations and activities may develop on the planetary surface.

Chemists have long since shown how the more complex inorganic compounds arise from simpler ones. In recent years, American scientists have also shown how molecules essential to organic life may develop. They have attempted to simulate the conditions and stimuli occurring on our planet several hundred million years ago.

At that time, the surface probably consisted of oceans of the simpler atoms. Without plants, there could be no oxygen or ozone shield. Consequently stellar rays would beat directly upon the oceans. The resulting reactions have been partly reproduced in the laboratory, with various groups of atoms and electrical stimuli. The product was amino acids. These are key acids necessary to the build-up of proteins, which in turn are essential to organic life.

What has particularly interested scientists is the fact that varying combinations of atoms under varying stimuli produced amino acids. The tendency to evolve molecules essential for the life process occurs in varying conditions.

Together with other finds, these experiments narrow the gap between chemistry and biology. The bridge between the two has not yet been found, but the continuing progress sustains scientific opinion that it exists: life naturally evolves in appropriate situations.

So far as we can observe, the evolutionary process may be taking place on at least one other of the planets in our solar system. Observing the uniformity of the Universe and the commonness of our Sun, leading astronomers today infer that similar processes are occurring on a proportionate number of the billions of planets estimated to be in our galaxy.

On the basis of our present understanding of Earthly evolution, it appears that plant life must come first, because it depends directly on Solar radiation. Once it appears, it discharges oxygen. The resulting build-up of atmosphere absorbs or scatters back about 30 percent of the Solar energy, including particularly the ultraviolet. This protection both preserves life and slows down the rate of transformation at the planetary surface.

The evolution of species occurs through genetic mutations. These may be stimulated by residual radioactivity at the surface; by such radiation as pierces the atmosphere; by thermal, chemical and unknown forces, internal or external. Experiments have shown that mutations are induced by such stimuli.

Radiation from stars like our Sun changes susbtantially. In the long run it rises steadily. Medium-term fluctuations raise or lower its intensity. These changes in stellar radiation not only determine whether life will evolve, but also the rate of duration of its evolution.

The long-run trend determines how long a planetary surface will be favorable to organic life. According to E. J. Oepik (*Scientific American,* June, 1958), Solar radiation became sufficiently intense for continuous life on Earth about 750 million years ago. Prior to that date, medium-term fluctuations may have stimulated the origin of life several separate times before continuous life became possible. About one billion years in the future, similar discontinuities may result from fluctuations around the long-term trend toward excessive radiation.

Fifty million miles further from our Sun, Mars now receives much less radiation. Observations indicate that only primitive forms of life, such as algae, lichens and fungi, have developed on its surface thus far. Provided the water shortage is not prohibitive, it should become more favorable as increasing radiation makes Earth less so.

Conceivably the ice-laden surfaces of Jupiter and the further planets may in turn become more hospitable to such life as can adapt to their gravity. At some point, however, the long-run curve of solar radiation will begin to rise sharply. Our Sun's expansion will reach explosive proportions, and life will no longer be possible in this planetary system.

During the hundreds of millions of years that the long-term trend favors life on a partic-

ular planet, the medium-term cycle markedly affects it. Oepik attributes Earth's 250-million year recurrence of Ice Ages to periodic declines in Solar radiation. During the six million years of an Ice Age, the ice cap may advance and recede. Such glaciations as well as other crustal disturbances select those species which can adapt to them.

The evolution of new forms may also be affected by fluctuations in radiation. Paleontology divides the history of life on Earth into a series of ages. Ages are characterized by the prolonged stability of their various species; the rate of evolution is slight. Shorter intervening periods separate the ages; during these, the extinction of old species and mutation of new ones apparently occur at a massive rate. Changes of temperature and radiation may account for these simultaneous extinctions and mutations.

Elemental sensitivity to radiation is thus a continuing process. The origin, rate, direction and possible conclusion of evolution are forms of interaction between variable stellar radiation and planetary enviroment.

The tendency of evolution is to absorb an increasing amount of Solar energy through the activity of increasingly complex forms of life. Simple forms, like algae, utilize Solar energy directly. A fuller use is achieved by interdependent organisms. Plants, insects, birds and other animals are able to absorb more energy by specialization and exchange.

Through mutation, these complex interdependent forms evolve. In the words of H. J. Muller,

> Living matter, unlike non-living, is by reason of its doubling and redoubling always tending to expand, not like a gas that becomes more dilute and feebler in the process, but with increase of its mass and no relenting of its pressure outward and into diverse corners and crevices. In fact, the pressure of the living matter tends to increase with its expansion, since at the same time, by means of its mutations, it is trying out all sorts of new versions of itself and perpetuating and sending furthest forward those that can expand the fastest and that can enter regions and situations that had acted as barriers to its earlier versions. (*Scientific Monthly*, May, 1957)

Mobility is essential to this process. The environment varies with seasons, latitudes and daily weather. As new species evolve, capable of utilizing environmental forms of energy more effectively than others, they expand through migration. Plants are as migrant as animals in the long run; the seeds of most botanical species are adapted to transport by wind or water, on the fur or feathers of animals and birds as well as in their intestines.

Over periods of time, continuing interchange of species permits those best adapted for any locality to displace those less adapted. The result is the development of interdependent ecological communities which take maximum advantage of the solar and other energy available in any particular climatic region.

Occasional natural calamities may denude whole areas. Migration permits species to survive such events and subsequently to revitalize those areas. Land which has been laid bare by fire, flood or other local catastrophe receives solar energy only to dissipate it into Space. Gradually the seeds of crude plant forms, borne by wind, birds or other carriers, take root. Certain types of insect life migrate into the area, attracted by the plants. When they have adequately developed the top-soil, more advanced plants move in, displacing the previous inhabitants and making possible the arrival of higher types of animal life. Thus, over a century or two, the area progresses to what ecologists call a "climax" community—a close-knit and delicately balanced system of plants, insects and animals.

Oceans bar migration of most land species other than man. Until modern times, the separate continents supported communities varying in their degree of adaption and energy-utilization. As a general rule, larger areas developed more advanced forms of life because they afforded greater opportunity for variation and selection. In the Americas and in Australia, species were fewer and often more primitive than those of the Afro-Eurasian land mass. They were still sparser on islands.

About a million years ago our highly-specialized form of life evolved on the large continent. Physically weak and dependent on other species for the conversion of Solar

energy, man has an intelligence which permits the use of tools. During 99 percent of the period from then till now, our ancestors experimented with stones, sharpening them for use in catching and processing other animals; their societies receded and advanced in the face of the cyclical glaciations of the present Ice Age. Then about 10,000 years ago, they developed carpentry. They began to exploit the environment, and gradually became the most mobile of species.

During the last five centuries, men have overcome the ocean barrier. As they crossed the seas with increasing frequency, our forefathers carried other forms of life. In part this process was intentional: they took their favorite trees, flowers and pets, as well as the plants and animals they wanted to consume. Probably to a greater extent, it was unintentional: seeds, insects and sometimes even larger forms of life chanced to accompany the voyagers. Darwin, among others, noted the beneficent effects of human mobility in advancing the levels of organic life on areas previously cut off from one another.

Transoceanic mobility was a big step when it occurred. But it has become evident that human powers far exceed this accomplishment. Men explore the highest mountains, descend to the oceans' depths, balloon into the atmosphere. The development of aerial flight and the first probings of outer Space have led to preliminary experiments in the direction of interplanetary exploration. There seems to be no limit to our mobility so long as environments at both ends of the trip are hospitable.

To expand our efficiency we have exploited other organic life and reduced the net absorption of Solar energy. But the cost is small compared to the possible gains. The achievement of interplanetary mobility would make it possible to expand wherever the temporary conditions in a variable Universe permit.

Here on Earth, we are familiar with minor variations and disturbances. Atmospheric changes give us cloudy or clear skies, wind, rain, snow, hail, lightning and the like. We adapt to these. The tilt of our planet's axis gives us seasons, and we adapt to these. Occasional disturbances include local hurricanes, tornadoes, floods and earthquakes.

*Photograph by Dr. V. Ben Meen*

*CHUBB CRATER FROM THE AIR—The crater, perfectly round and more than two miles across at the rim, is an unmistakable landmark from the air. It was explored and proved to be of meteoritic origin by a National Geographic Society-Royal Ontario Museum expedition during July and August, 1951.*

Our mobility permits us to minimize losses and afterwards to restore life to demand areas.

On a larger scale the cosmos offers many hazards, as well as stimuli, to planetary life. These occur at a leisurely pace, spanning millions of years. But they are correspondingly much greater, and sometimes destructive to celestial bodies. Long as are the time-periods, they are only fractions of that needed for the evolution of advanced life. Consequently an effective organic response must include sufficient specialization and mobility to adapt to them.

In addition to the cycles of Solar radiation, other events occur. As yet we know too little to predict them all; but the time spans between major events appear to be much longer than between minor ones.

Some of the hazards of the Universe are relatively small—useful as reminders that they do exist. Perhaps a few thousand meteors strike our atmosphere each day. Occasionally one is large enough to come down to the surface and even more infrequent ones are

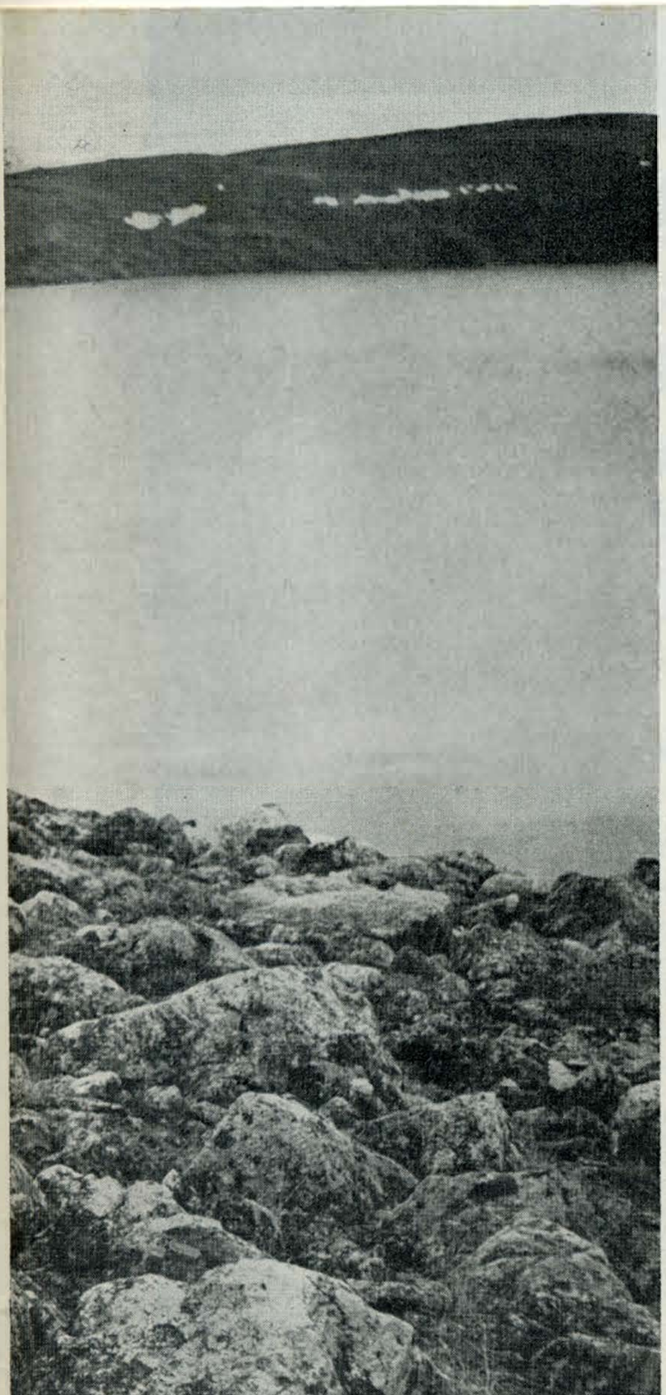
*A National Geographic Society-Royal Ontario Museum Expedition under the direction of Dr. Victor Ben Meen, Museum geologist, in 1951 probed the mysterious crater daily for four weeks and concluded that it was formed by the crash of a meteor some 30 to 150 centuries ago. Frederick Chubb (above, left), prospector and explorer who first spotted the crater, and Dr. Meen (right) describe their field procedure to a visiting scientist, Dr. I. W. Jones, chief of the Geological Surveys Branch of the Quebec Department of Mines.*

large enough to mark the surface. Canyon Diablo in Arizona is ¾-ths of a mile across and 600 feet deep. Chubb Crater in Canada is bigger. Other craters may have been formed and subsequently erased by wind, rain and organic life. The 30,000 craters on the earthward side of the Moon may illustrate what our planet would look like without these erosive forces.

Asteroids are much fewer and less likely to collide with our planet. On the other hand, their size—up to 400 miles in diameter—would end life over a substantial area. Comets range from 4 to 20 times Earth's diameter; but they are so thin that collision would ordinarily have little effect.

Collisions between planets or other large objects may occur. The asteroid belt, the meteors and the bodies reflecting zodiacal light are all thought to be remnants of a planet which used to circle at one remove from us, between Mars and Jupiter. We do not yet know the cause of its break-up; it has tentatively been attributed to collision.

Another possible type of planetary disturbance is a shift of axis while remaining in orbit. Magnetic analysis of ancient rocks indicates that Earth's polarization has been at various times opposite and perpendicular to its present direction. The location of ice-cap remnants below, and on, the present equator may be interpreted in support of what Gold and Hoyle call "polar toppling." However, there is no agreement yet on the evidence or on the internal or external forces which might cause such shifts.



On a water-dominated planet like ours, polar toppling would induce continental floods. A Great Flood, the story of which is told in most ancient sacred/epic works, perhaps really happened. As those oral traditions indicate, however, partial survival of animal life is likely, especially if preparatory measures have been taken.

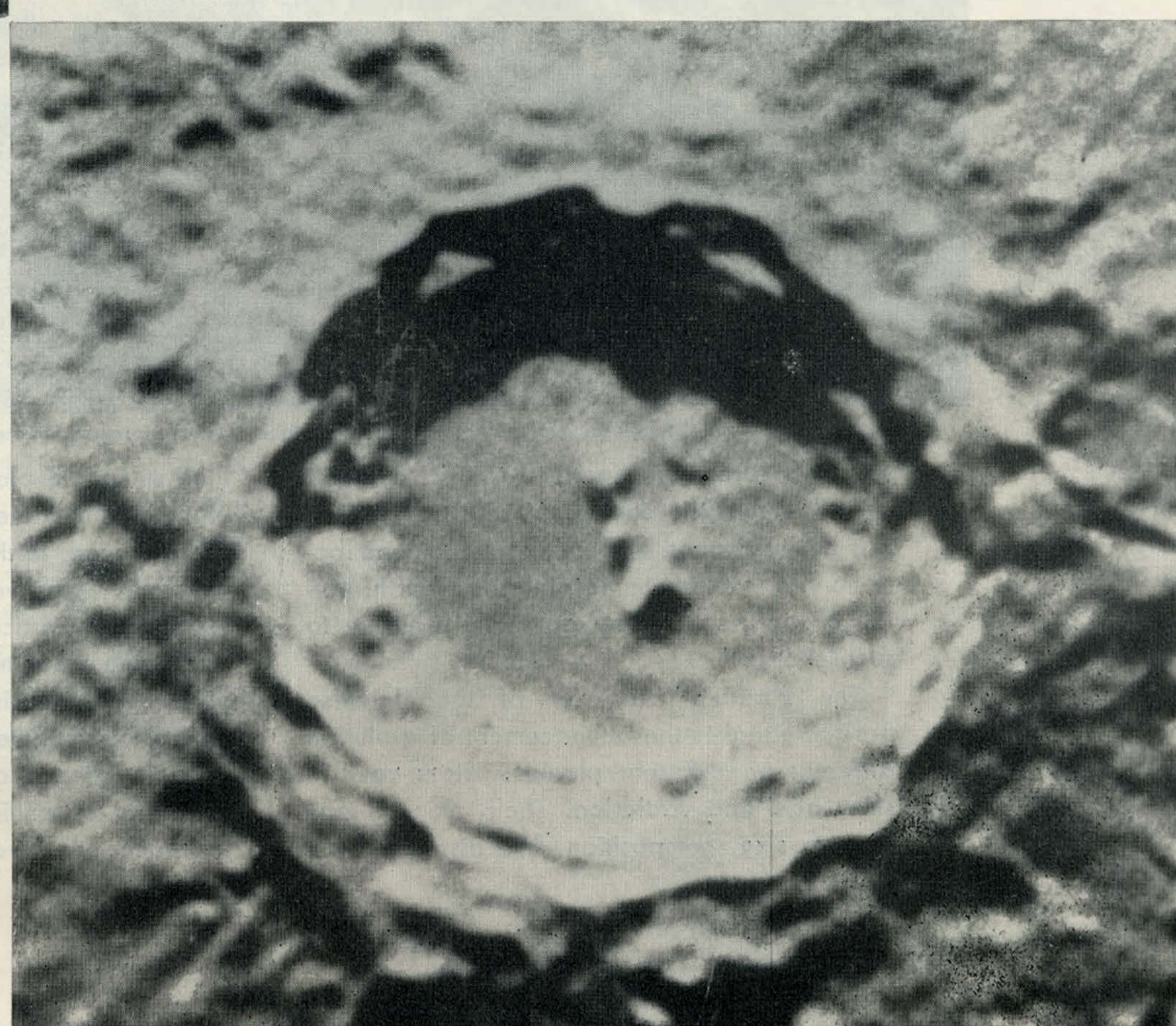
The chance of collision between stars of different galaxies seems to be greater than it is between stars of the same galaxy. Galaxies are quadrillions of miles across, and move at thousands of miles per second. In consequence, their paths occasionally intersect. Members of the Coma metagalaxy, for instance, are sufficiently close together that intersection of two or more of its galaxies must occur every 150 million years on the average.

Several galactic intersections are currently under observation (a most striking one at NGC 5128). But they are too far away for us to ascertain much about them, except that they are the loudest transmitters of radio noise in the Universe. Stars are so widely spaced that galaxies probably pass through one another with only a few actual collisions. Near misses might affect stars and their planets in various ways. Such effects could stimulate life on some, retard or destroy it on others.

These are the types of turbulence which

*Comparison of the enlarged view of the Moon's crater Copernicus indicates striking similarities to craters on Earth.*





*Locking the Earth's dense atmospheric protection, the Moon hos been scarred by a perpetual deluge of meteorites.*

scientists are investigating today. Natural events disrupt the courses of celestial bodies, just as hurricanes and other phenomena occasionally overwhelm localities on Earth. Living organisms must be especially sensitive to such events.

The variable character of the Universe probably makes the advancement of evolution different on different planets. Stars vary in size, age and radiation. Their planets may vary in size, composition and distance from their suns. If evolution proceeds on billions of planets simultaneously, conditions, stimuli, disturbances and intervening time periods will vary. Some variations will encourage the growth of advanced forms of life. Others will not. Some areas may be relatively rich, others relatively barren in the evolution of plant and animal communities.

The evidence of this planet suggests that hundreds of millions of years are required to reach our level. Over so long a period

environmental changes may exceed favorable limits. Radiation is a principal determinant. A planet now well-suited for life may, in a preceding age, have undergone an excessive drop or increase in radiation. Fire or ice may have left only primeval organisms to take advantage of the intervening favorable period. Other hazards may have had similar effects.

More often than not, the evolution of life on a planet may be interrupted before it reaches advanced stages. This conclusion parallels biological observations here. Nature's lavish method is to initiate far more life than need ever reach maturity.

On the other hand, some planets may support a more luxuriant variety of life than has evolved on Earth. These would offer species which could advantageously be transferred to less developed planets. Somewhere, too, beings may have evolved at least as complex and as mobile as ourselves. Possible relationships between such beings from different planets stretch our imagination (and may stretch theirs also).

Among planets, differences would probably be much greater than those which our ancestors discovered between the continents and islands of Earth. The natural remedy is the same. Mobility allows life to recede, advance and adapt to changing conditions. Through mobility, it can strive for optimum development in every area where conditions are currently favorable.

Migrant life can revitalize areas denuded by turbulence. It can seek opportunities on planets just entering favorable periods. It can explore the attendant bodies around new stars. In the earlier stages of evolution, galactic intersection makes the future of an individual planet uncertain; but to an advanced and agile community, it offers a rare opportunity for intergalactic migration.

If time, wisdom and circumstances are adequate, we on Earth may become mobile in Space. Seeking expansion, our species is fully involved in the organic response to the challenges of the environment. We are part of the Universe. We share the natural instinct to enlarge the domain of present as well as of future generations. Like those who went before us, we probe new frontiers. We are explorers, pioneers.