THE ECOSPHERE IN THE SOLAR PLANETARY SYSTEM

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(Helio-ecosphere)

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On our planet Earth we observe different climatic zones such as tropical, subtropical, moderate, subarctic and arctic zones. They are distinguished by variations or even limitations concerning flora, fauna and civilization. The study of the causes, expansion and characteristics of these climatic zones is the task of a branch of biology called geographic ecology.

The differentiation of the earth's surface in climatic zones is caused by the intensity of the Sun's radiation which varies primarily with its angle of incidence. Dependent upon whether the rays strike the globe vertically or obliquely, they are subjected in a lesser or higher degree to an attenuation by absorption, reflection and scattering before they reach the Earth's surface. On Mars too, different climatic zones are very definitely observed between the poles and the equator (areographic ecology).

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Now, if we apply ecological considerations upon the planetary system as a whole, we must consider primarily the <u>distance of the planets from the Sun</u> as responsible for variations in the <u>intensity of solar radiation</u> on the various planets and the ecological conditions found thereon (planetary ecology).

We should expect the possibility of life - such as the kind we know (based on the carbon atom) - only on planets found in a certain distance from the Sun.

As a point of departure, we choose the radiation conditions as they are found in the distance of the Earth from the Sun (93 million miles or 149 million km.). The radiant energy received in this distance by 1 cm^2 area and per min. in the form of heat, light and rays of other wave lengths is equal to 1.94 cal. This value is known under the name solar constant. According to the inverse square to the distance law, at the distance of the orbit of Mars (134 million miles or 228 million km.) this value decreases to a little less than half. In the area of Jupiter's orbit (466 million miles or 777 million km.) it amounts to only 1/27th of the Earth's value. Pluto, 3670 million miles or 5872 million km. away from the Sun, receives per area unit only 1/1600 of the amount of energy that the Earth receives. In the distance of Venus' orbit (64 million miles or 108 million km.) however, the respective solar constant is more than one and one-half and on Mercury (35 million miles or 58 million km.) more than six times greater than the value in the vicinity of the Earth. Such are the radiation conditions within gigantic globular shells, which must be imagined in the distances of the planetary orbits, concentrically surrounding the Sun.

Solar radiation, when absorbed by such matter as an atmosphere, produces either or both physical and chemical effects within the atmosphere. In this discussion we are interested in the physical and chemical conditions that are necessary for the existence and flourishment of life.

The Biotemperature Belt in the Planetary System

One of the most important physical-ecological conditions is temperature. Active life processes are possible only within a certain temperature range, from some degrees below the freezing point of water to about 50°C. Beyond this range, life becomes dormant or latent and later perishes. In examining the possibility of life in any medium, the possibility of active life is what counts.

If we now consider the measured temperatures of the planets, as shown in recent astronomical literature, we obtain a set of figures which conform to a considerable degree with the values obtained from the respective planetary solar constants. Figure 1. The temperature on the sun-side of Mercury amounts to over 400°C. That of the atmosphere of Venus varies between +100°C and -10°C. On earth, temperatures between +60 and -60°C are observed. Martian temperatures range between +25 and -70°C. At the visible surface of the atmosphere of Jupiter, a temperature of -160°C is reported. For Saturn the figure is -180°C, for Uranus -190°, for Neptune -220° and for Pluto -240°C.

Figure 1 further shows in what range of temperature active life - as we know it - is possible.

This comparison shows that only Venus, Earth, and Mars cover - partially or totally - the range of ~~biological~~ temperatures biologically required.

Beyond Venus - on Mercury - it is too hot; beyond Mars - from Jupiter to Pluto - it is too cold. Thus, we arrive at a temperature belt surrounding the Sun within which active life on planets is conceivable, outside this belt it is not; Venus lies in the warm, Mars in the cold border zone and Earth in the golden moderate middle of this biotemperature belt in the planetary system.

The "Liquid Water Belt" in the Planetary System.

The temperature factor logically leads to the question of the presence of water in a biologically useable form, that is, in a liquid state. Water is a prerequisite for the existence of life. It serves as the solvent of the various constituents in protoplasma and body fluids, but also - like carbon dioxide - water serves as raw material in the photosynthetic production of organic matter and oxygen. Without water - no life. If a planet does not contain water in its biologically useable form, such a planet could not support life. This is true of the larger planets where water might be present only as ice. The water content in the Martian air is very low and may exist only in the form of vapor and ice crystals. The white polar caps, which melt away in the Martian spring are probably thin layers of hoarfrost. And there are no lakes and oceans. So, compared with the Earth, Mars is a very dry planet with perhaps sufficient moisture to support lower forms of life. In the Venusian atmosphere water has not yet been detected. However, this is still a matter of astronomical dispute. Since Mercury has no atmosphere and a very high temperature, the presence of water is out of the question.

H. Shapley, recently termed that area in the planetary system, within which liquid water is conceivable on planets, the "liquid water belt" - a very instructive and appealing term. This is the second characteristic belt in the planetary system.

But there are still other ecological factors to consider; one of these that we have already touched upon in the water problem is: the chemical composition of the planetary atmosphere - especially the content of oxygen and oxygen compounds such as carbon dioxide.

The Oxygen Belt in the Planetary System.

Oxygen is the key element in the biological energy liberation. The reaction in question is the biological oxidation in the cells. This oxygen reaction results in the breakdown of the foodstuff molecules down to the smallest possible compounds like water and carbon dioxide. The gain of energy is therefore high. Biological oxidation has made possible the development of organisms to higher stages. This reaction requires supply of oxygen from the environment.

There is another biological reaction for energy liberation which does not need a supply of free oxygen. This is a simple splitting of the molecules, a process which does not lead to a breakdown into the smallest possible compounds. The amount of energy gained in this process, also called fermentation, is therefore low, but sufficient for lower organisms. Though molecular oxygen is not required in this process, oxygen is involved insofar as the respective foodstuff molecules contain oxygen intramolecularly.

Carbon dioxide, another biologically important chemical, is - like water - one of the raw materials for the buildup of organic matter in the process of photosynthesis in green vegetation.

It is understandable that the question of the possibility of life is always closely associated with the presence of oxygen and carbon dioxide in any environment.

The chemical composition of the planetary atmospheres especially the presence of oxygen and carbon dioxide - to a large extent - again depends upon the Sun's radiation and consequently on the distances of the Planets from the Sun. Ultraviolet of solar radiation especially causes considerable changes in their chemistry. The photochemical reactions in question are photo-dissociations and recombinations.

In order to understand this entire problem better, we must take a look upon the historical evolution of the Earth's atmosphere from its primitive stage - the protoatmosphere to the present.

This subject matter has been discussed in a most inspiring manner in the recently published books of Kuiper and Urey.

The protoatmosphere of the Earth some $2\frac{1}{2} \times 10^9$ years ago showed a chemical composition very different from that of the present day atmosphere. The present day atmosphere contains oxygen, oxygen compounds and nitrogen. It is an oxidized and oxidizing atmosphere. It has oxidizing power. Chemically, the present atmosphere is essentially an oxygen atmosphere. The protoatmosphere, however, consisted mainly of hydrogen and hydrogen compounds such as Methane and Ammonia. Furthermore, of water vapor and Helium. It was a reducing and reduced atmosphere. It had no oxidizing power. Chemically, the protoatmosphere was essentially a hydrogen atmosphere.

But soon a change set in. According to recent astrophysical theories, by means of photodissociation, the water molecules at the border of the protoatmosphere were split into hydrogen and oxygen. The lighter hydrogen escaped into space, and the heavier oxygen remained. With the appearance of this initial oxygen the protoatmosphere attained oxydizing power. Ammonia (NH_3) was oxidized to free nitrogen (N_2) and water, and Methane (CH_4) to carbon dioxide (CO_2) and water. (In addition large amounts of carbon dioxide were injected into the air by volcanic eruptions.) In this way the atmosphere became more and more oxidized. With the appearance of chlorophyl more than 1½ $\times 10^9$ years ago, this was accelerated by the process of photosynthesis. The oxygen thus produced oxidized the remaining hydrogen compounds and in addition an excess of oxygen accumulated to rather large amounts, such as are observed in the present day atmosphere. This stock of atmospheric free oxygen (O_2) amounts to 1.2×10^{15} metric tons.

Such was probably the course of events in the evolution of the Earth's protoatmosphere to the present day atmosphere in which we live. Only in an oxygen atmosphere could higher organisms develop; only in such an atmosphere can man exist. In the hydrogen atmosphere of the remote past - if some initial oxygen was already available, microorganisms like hydrogen bacteria, methane and ammonia and iron bacteria could have found a suitable environment.

When we now consider the present day atmospheres of the other planets, we find an interesting chemical parallel to that which we have just discussed.

Astrophysics teaches us that the atmospheres of the outer planets - Pluto, Uranus, Neptune, Saturn, and Jupiter, consist of Hydrogen and the Hydrogen compounds, Methan and Ammonia and frozen water. Mars contains oxidized compounds like Carbon Dioxide but no free oxygen or only traces of it. Because of its lower gravitational pull - which is only 38 percent of that of the Earth - proto-Mars probably lost its free oxygen into space. Venus has a completely oxidized atmosphere and also no free oxygen. The higher temperature of proto-Venus, due to its nearness to the Sun, was probably the cause of its oxygen loss. Mercury - the smallest of the planets and the closest to the Sun, could not possibly hold an atmosphere because of its very high temperature and low gravitational pull.

This survey shows - in a most impressive manner - the photochemical effectiveness of solar radiation upon the planetary atmospheres. The atmospheres of the outer planets in their remote deep freeze areas apparently have been only slightly affected by the Sun's radiation. Undoubtedly they may have preserved their gaseous envelopes of the proto-atmospheric stage up to the present time. The atmospheres from Mars to Venus, however, have undergone a similar developmental change in their chemistry such as that of the Earth.

We recall that in the evolution of the Earth's atmosphere - from the far distant past to the present - a transformation from a hydrogen atmosphere to an oxygen atmosphere, took place. Now - considering all the planets in their present state - we note the same chemical sequence when we travel through the planetary system, beginning at the remote distance from the Sun to its immediate neighborhood; namely, a transition from Hydrogen and Hydrogen compounds containing atmospheres to oxygen and/or oxygen compounds containing atmospheres. Figure 2. Chronologically, the atmospheres of the outer planets may all be about the same age as those of the inner planets, but they are apparently younger with regard to their material metabolism as effected by the Sun's radiation. If this is so, then indeed we recognize in the chemical composition of the planetary atmospheres - in their sequence from the outer to the inner planets - "a recapitulation of the ontogeny of the Earth's atmosphere" to use a phrase famous in paleobiology.

Now in this discussion we are interested mainly in that range of the planetary system where oxygen and/or oxidized compounds are found, as on Mars, on Earth, and on Venus. Apparently, only within a certain distance from the Sun is radiation strong enough to change the atmospheres to this chemical stage. In the same manner as we speak of a biotemperature belt, and a liquid water belt, we may also speak of an <u>oxygen belt</u> in the planetary system. The Earth, however, stands out with an additional high stock of free oxygen; the Earth alone was able to accumulate free oxygen and to hold it. It is the oxygen planet par excellence.

With this oxygen belt we should also include Carbon Dioxide which, together with water as raw material, makes possible the photosynthetic production of oxygen by green vegetation.

<u>Ecosphere as a General Concept</u>.

As just explained, we find - only within a certain distance from the Sun - temperatures on the planets, which permit active life. (biotemperature belt). In only a certain area water can be present in liquid form on planets ("liquid water belt.") And in a certain area we find planetary atmospheres that contain oxygen and/or oxygen compounds. (oxygen belt). All of these belts lie in about the same distance from the Sun. If we wish to refer to all of these ecological factors with a single term, the more general term "ecological belt" or "<u>ecosphere</u>" of the Sun would be the appropriate designation.

The ecosphere of the Sun is a biologically defined concept. It indicates a zone, surrounding the Sun, in which the radiation on the one hand does not exceed the ecological maximum and therefore is not biocidal either directly or indirectly through the other ecological factors affected by it - and on the other hand, does not fall below the ecological minimum. The decisive factor is the distance from the Sun.

In our planetary system this ecological belt evidently extends from the area of Venus to beyond Mars, roughly from about 50 to 150 million miles distance away from the Sun. The zone itself is therefore about 100 million miles wide. This corresponds to a mere 3 percent of the total reach from the Sun to Pluto, The solar ecosphere is therefore a relatively narrow zone within the planetary area.

The ecosphere of the sun represents a globular shell in which planets in many different planes are conceivable, all enjoying the beneficence of the Sun's radiance. But in our solar system all the planets revolve generally in about the same plane; therefore, the area covered by the planets represents only a small flat cut of that globular shell.

The ecological qualities of the planets naturally depend upon some other factors besides the distance of the Sun. The planet's mass is one; its period of rotation, its heat production by radio-activity, and the presence of an atmosphere - are others. This has been described by P. Lowell in his book "The Evolution of Worlds" (1910). But the distance of the planets from the Sun may be the predominating factor in their present state of development. Using a biological concept like that of the solar ecosphere makes this situation more understandable.

Other Suns

I would like to conclude this discussion with a brief remark on the question of other Suns with planetary systems. H. Shapley estimated recently that out of more than 10^{20} stars in the entire universe, 100 million might have acquired planetary families. This being so, we might suppose that just as many stellar ecospheres are found in the Universe. Shapley assumes further that, of the 100 million planetary families, perhaps one in 1,000 may have developed life of some persistence on a higher level.

This estimate would yield one bioplanet per (10^9) stars, or something like 100,000 in all. Assuming that a stellar ecosphere may offer room for more than one bioplanet, we might find that the number of planets in the Universe that permit life is somewhat greater. Yet, all of this is, and probably must forever remain, a matter of delightful speculation.

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