ARIDITY AND EVOLUTION.

THE EFFECT OF DRYNESS ON LIFE.

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FROM every excursion which the biologist has made hitherto into speculation as to the origination of living or self-generating matter, and its development into organisms, in which he has called to his support supposed extreme or unusual intensities of terrestrial and atmospheric conditions, he has been ruthlessly recalled by the geological historian with the reminder that the general composition of the atmosphere, its pressure, the temperatures, and other conditions prevalent on the earth's surface were uniform and continuous with those now encountered and not widely different in their total departure in any stage of the earth's development in which life might have originated.

Knowing full well that life did not always exist, that self-generating matter, so far as our observations go, is not now originating, we persistently return to the idea that the beginning of life must have occurred at some stage of the earth's history more favorable to such action than the present.

THE ORIGIN OF LIFE.

In the search for supporting ideas upon which to base speculation, two conceptions serve as encouragement for a renewed attack upon this fascinating problem. One is embraced by Chamberlain's planetesimal theory of the growth of the earth and the attendant modification of surface conditions, which necessarily showed a complex widely different from the present; and the other is one growing in favor with physiologists, to the effect that the essential activities of living matter rest upon catalysis and enzymatic processes, with the characteristic reaction velocities directly affected by internal and external limiting factors.

The protamic nucleus may be taken to represent the first form in which self-generating matter might be said to have the characters of protoplasm; but previously to its synthesis, there must have occurred an increasingly complex series of carbon compounds with hydrogen, oxygen, nitrogen, sulphur, and phosphorus, while iron, calcium, magnesium, and potassium are also involved in its activities at the present time. That these main constituents were present in the atmosphere at partial pressures of varying intensity, and that unstable carbides, nitrides, phosphides, and sulphides brought by infalling planetesimals were passing into more stable unions, with the formation of hydrocarbons, ammonia, hydrogen phosphide, etc., is suggested by Chamberlain; and the possible interactions and combinations might result in the synthesis of very complex substances, well up toward the simpler forms of living matter. The hypothesis formulated by him also assumes that the surface of the earth was unworn piled talus, but little of which had gone into solution. The development of the hydrosphere moistening this layer, and forming pools and small bodies of water all exposed to the light of the sun, together with the variations in temperature, partly due to the heat of impact of infalling bodies, the influence of magnetic fields induced by bodies circulating about the earth would determine the paths of ions and electrons traversing them, while in addition, other states of ionization due to radial activity, would all be possible contributory factors in making a synthesis that might form a beginning of the physical basis of life. Any resulting thermo-catalyzer would be a possible agent for self-organization; and in the development of an organic type, its characteristic activities would consist in the degradation or reduction of the potential energy of the medium or substratum and the oxidation of the acquired substances. Living matter is, in fact, a thermal engine in which the oxidation is, comparatively, exceedingly slow.

EXPERIMENTAL PRODUCTION OF SELF-GENERATING MATTER.

It seems quite probable that combinations similar, analogous, or even identical with the earliest forms of living matter might now be produced in the laboratory, in inclosed spaces or under special conditions. Doubtless compounds of much greater intricacy have been built up; but while we might make such substances, yet it would be extremely difficult for us to furnish the supply of material and the continuance of conditions which would permit this matter to exercise its initial functions to any appreciable extent. The tests and criticisms which have been applied to the results of the few essays that have been made for the production of bodies which would be self-maintenant in a suitable medium, have been for the most part misdirected. Thus in the consideration of the hitherto unsuccessful efforts to produce bodies simulating some of the properties of self-generating matter, tests for the physical and chemical properties of protoplasm,

as well as for phenomena of the cell, have been applied, regardless of the fact that the cell probably stands removed by a million years of evolution from the simple living material which first took shape, and represents in fact simply a successful form of organism, and by no means the only possible morphological organization.

PROPERTIES OF LIVING SUBSTANCE.

After growth and decay, the next most important property of living matter is that of irritability, of impressibility and adjustment to environment. The primitive substance of protoplasm endured because of a capacity for withstanding the current range of temperature and insolation, and this endurance was made possible by fairly automatic adjustments, one of the simplest of which is encountered in recognizable form in living plants to-day in the decrease of water content, which follows lower temperatures acting upon protoplasm. Few adjustments are so simple, and of course more complicated ones become possible as atomic group after atomic group was added to the one constituency of living matter.

So far the properties suggested are those common to all living forms, but there must have ensued many differentiations of living matter, of which we have two survivals in those developing into plants and into animals. It seems probable that the first specialization resulted from the formation of substances in some of the living masses which converted radiations of certain wave-lengths into heat and other forms of energy active in promoting the reduction processes. The highest development of this power of absorption of light rays is to be assigned to chlorophyll, but preceding the formation of this very intricate and unstable substance there may have occurred a series of other compounds acting as screens capable of absorbing rays from the lower part of the spectrum, of which the reddish and bluish pigments of the lower algae are surviving examples. Many disintegration products constituting the reds and blues of plant tissues sustain physical relations of a similar character to sunlight.

ENVIRONMENTAL RELATIONS.

It is not possible to formulate any rational conception of living matter without including its environmental relations. These become of the utmost importance at the moment of formation of self-generating matter; and it may be assumed with perfect safety that of all the possible synthetic processes, only those which ensued in the presence of a medium which furnished substances suitable for building material could survive. Furthermore, when the accumulation of this material and its specialization is considered, it is apparent that successful origination occurred only on solid or semi-solid substrata rather than in undifferentiated solutions in open waters. Still, an abundance of this liquid would be of great importance to the colloidal masses which we may think of as the earliest living things, and as will be shown presently, water has continued to be the most important of all of the constituents of environment, especially with regard to the vegetal organism. The first method of multiplication of individuals or colloidal masses undoubtedly consisted of simple fragmentation resulting from the accumulation of a mass too great to be held together by surface tension, and the separation of these masses must have been accomplished, or made possible, by flotation, which continues to be one of the most efficient agencies in the dissemination of plants, a fact especially emphasized by the results of our studies upon the re-vegetation of the Salton basin.

Wherever portions of the colloidal mass came into contact with solid substances, gelation or aggregation ensued, and the layers of material thus differentiated would give form, and stability in place, representing the earliest form of anchorage organ, which must have been the first member of the vegetative axis to take on definite functions and structure. In this as well as in other features of the plant, evolutionary development was slow so long as the monotonous conditions of an aquatic habitat were to be met.

The present occasion does not permit a discussion of the probable evolutionary development of the vegetal organism from the stage of simple colloidal masses to the gametophyte, and the evidence at our disposal is so entirely lacking that such discussion would be entirely speculative. It will be quite pertinent to call attention to the fact, however, that these earlier rhizoidal anchorage organs stand in no direct or genetic relationship to the roots of modern seed-plants.

THE ORIGIN OF A LAND FLORA.

As has been so succinctly described by Bower, types of vegetation with gametophytic reproduction must necessarily remain aquatic, or at least hygrophilous, since free water was necessary for the movements of gametes in effecting fertilization. Furthermore, the stimulus of desiccation, when such forms were stranded or left above the water level, does not appear to have any direct consequence in the way of development of incidental structures which might facilitate such sexual reproduction, a fact probably due to the morphogenetic limitations of gametophyte, not easily understood.

The problem of aridity was in reality solved in quite another way, by the prolongation of the vegetative existence of the germinating zygospores formed by the union of the gametes, finally resulting in the independent sporophyte. The sporophyte was not dependent upon free water for any part of its existence, and its individual occupation of drier areas was accompanied by a development of the anchorage organ anew, this time from a highly developed shoot-like axis, and the differentiating effects of desiccation upon the root have been scarcely less marked than those of the shoot.

The necessity for anchorage was even greater than before, but now the nutritive salts no longer bathed the entire body, but were present only in hygroscopic layers on the soil particles with a vertical distribution not uniform and with much horizontal irregularity. The formation of absorbing mechanisms and conducting tissues has been followed by a refinement of form and habit reaction in the modern plant as shown by the researches of Cannon, so that in the language of the systematist the appreciable features of the root system doubtless present diagnostic characters quite as marked and as easily recognizable as those of the shoot.

So long as the gametophyte retained its separate existence, however, and depended upon free water for its reproduction, there could be no real land flora, since the plant must stand, as it were, with one foot in the water. The sporophyte waxed in importance unceasingly, however, by the development of the shoot and root systems until its vegetative activity overshadowed those of the gametophyte, its protective tissues finally inclosing the sexual generation, and with the formation of the pollen tube, the seed-plant became wholly able to get away from the stream margin, the low flat moisture-saturated land, and to occupy great continental areas and mountain slopes.

SCARCITY OF FOSSIL REMAINS IN ANCIENT DESERTS.

The total area of deserts at the present time is equal to about one-sixth of the total land exposure, and undisputed evidence is at hand that extended arid areas existed in all of the great geological periods. Since aridity or humidity depends upon topography and the prevailing winds, it follows quite naturally that these ancient deserts did not necessarily occupy positions coincident with the deserts of the present. Thus the facts seem to indicate extensive desiccation in what is now eastern America and parts of Europe in the Lower Carboniferous and Permian, while some coincidence of locality is found in arid areas in Wyoming and Texas. While evidence is accumulating to show that great swings of variations in climate are in progress in various regions, yet it would be difficult to demonstrate the proportion of arid area to the total land area in any previous period, and thus give a quantitative basis for the conclusion that the earth's surface is undergoing progressive desiccation.

It is noteworthy that formations which give evidence of desert conditions are notably free from fossil plants and contain but little in the way of animal remains. At the time of these earlier periods of aridity, vegetation had not developed forms capable of occupying dry land. During the Carboniferous, however, great areas of low-lying land existed in which conditions for gametophyte reproduction were very favorable, and a luxuriant development of ferns and related forms was possible.

ARIDITY; THE MOST IMPORTANT FACTOR AFFECTING THE DEVELOPMENT OF THE PLANT.

The seed-plant with its pollen tube and vascular system may be considered as the major vegetational response to limitations of the supply of moisture, and desiccation has been and continues to be the most important condition affecting the evolutionary development of plants. Temperatures alone have been unduly drawn upon in the interpretation of distribu-

tional features of ancient and existing floras, a fact made more plainly apparent by recent observations at the Desert Laboratory, in which it has been found that several species range over a vertical mile. Such species endure cold of 35 deg. C. and have a growing season of less than a hundred days in the more boreal or alpine portion of their ranges, while in the southern or lower localities inhabited by them, temperatures of 48 deg. C. may be encountered; the growing season extending over 300 days; the thermometer going below

the freezing point not more than 12 hours during the entire year. It is no surprise, therefore, that it is learned that there is no single feature in the structure and function of plants that with perfect assurance may be connected with the influence of temperature alone, although alpine and polar floras bear a distinct aspect by reason of a combination of conditions of moisture, insolation, duration of seasons, and course of humidity. While temperature is not in itself a direct factor in

shaping the general trend of evolutionary development in plants, yet it is indirectly concerned by the influence exerted upon precipitation, and the relation of the amount of rainfall to the possible evaporation. The great periodic changes in climate, produced by whatever cause, may be taken to have affected vegetation chiefly through the desiccation effects, which not only determined the ranges and habitats of forms, but also played a predominant part in evolution. (To be continued.)

THE ORIGIN OF THE SATELLITES.*

A NEW THEORY.

BY PROF. T. J. J. SEE.

In a paper presented to this Society January 30th, 1909, grounds were adduced to show that the planets and satellites of the solar system have not been detached from the central bodies which now govern their motions, by acceleration of rotation, as supposed by Laplace, but that all these masses had been captured or added from without, and have since had their orbits reduced in size and rounded up under the secular action of the nebular resisting medium formerly pervading our planetary system. In proof of this view a table was calculated to show the times of rotation of the sun and planets when these globes were imagined expanded to fill the orbits of the bodies revolving about them, according to the mechanical principle of the conservation of areas, in the forms of a criterion proposed by Babinet in 1861. This argument that the planets and satellites have been captured, and not detached, as has been generally supposed since the time of Laplace, is very satisfactory; and to many minds was, no doubt, quite convincing. We shall now give a brief outline of a new proof, referring the reader for a fuller statement to the papers which have been communicated to the *Astronomische Nachrichten*.

Table showing the application of Babinet's criterion to the planets and satellites when the sun and planets are expanded to fill the orbits of the bodies revolving about them.

Solar System.			
Planet	R_p The Sun's observed time of Rev.	P_o Observed period of planet	R_c Time of the Sun's rotation calculated by Babinet's criterion
Mercury	25.3 days = 0.069267 yrs.	0.24085 yrs.	479 yrs.
Venus		0.61237 »	1673 »
The Earth		1.00000 »	3192 »
Mars		1.88085 »	7424 »
Ceres		4.60345 »	24487 »
Jupiter		11.86 »	86560 »
Saturn		29.46 »	290962 »
Uranus		84.02 »	1176765 »
Neptune		164.78 »	2888533 »

Sub systems.				
Planet	Satellite	R_p Adopted rotation of planet	P_o Observed period of satellite	R_c Time of planet's rotation calculated by Babinet's criterion
The Earth	The Moon	1 day	27.32166 days	3632.45 days
Mars	Phobos	24 ^h 37 ^m 22 ^s 97	7.6542 hours	190.62 hours
	Deimos		30.2983 »	1193.52 »
Jupiter	I	9 ^h 50 ^m 28 ^s	11.9563 hours	64.456 hours
	II		1.7698605 days	14.60 days
	III		3.5540942 »	36.900 »
	IV		7.1663872 »	93.933 »
	V		16.7535524 »	290.63 »
	VI		250.618 »	10768.8 »
	VII		265.0 »	11602.4 »
	VIII		930.73 »	61997.2 »
Saturn	Inner edge of ring	10 ^h 64 ^m 1 ^s	0.236 days	0.6228 days
	Outer edge of ring		0.6456 »	2.383 »
	Mimas		0.94242 »	4.2902 »
	Enceladus		1.37022 »	7.0615 »
	Tethys		1.887796 »	10.822 »
	Dione		2.736913 »	17.751 »
	Rhea		4.517500 »	34.620 »
Saturn	Titan	10 ^h 64 ^m 1 ^s	15.945417 days	186.05 days
	Hyperion		21.277396 »	273.06 »
	Iapetus		79.329375 »	1580.1 »
	Phoebe		546.5 »	20712 »
Uranus	Ariel	10 ^h 11 ^m 12 ^s (cf. A. N. 3992)	2.520383 days	33.714 days
	Umbriel		4.144181 »	65.435 »
	Titania		8.705897 »	176.05 »
	Oberon		13.463269 »	314.83 »
Neptune	Satellite	12 ^h 58 ^m 48 ^s 17 (cf. A. N. 3992)	5.87690 days	141.8 days

1. In the year 1836 the celebrated German mathematician Jacobi communicated to the Paris Academy of Sciences an integral of the differential equations of motion for the restricted problem of three bodies; the system being made up of a sun attended by a planet revolving about it in a circle, and a particle of insensible mass. Jacobi remarks that the integral may be applied to a body such as the terrestrial moon.

2. In 1877 Dr. G. W. Hill developed and greatly perfected the theory of Jacobi's integral, and applied it to the Lunar Theory in a series of celebrated papers.

* An abstract of report presented to the meeting of the directors of the Astronomical Society of the Pacific, June 25th, 1909.

Hill's work has since been the basis of the profound researches of Poincaré, Darwin, and others on Periodic Orbits and related topics in celestial mechanics.

3. Dr. Hill showed that in the restricted problem of three bodies, implied in Jacobi's integral, there is a partition of the whole space into three parts—one about each of the large bodies, the sun and planet, and a larger domain inclosing both bodies—within which the power or control over the particle is vested in the two bodies individually and collectively, respectively. The closed surface about the earth includes the orbit of the moon, and the orbits of the other satellites in like manner are within the closed surfaces about their several planets; and Dr. Hill remarks that this arrangement is necessary to secure stability (cf. Hill's "Collected Mathematical Works," vol. i, p. 330).

If a satellite is once within this region with the surface of zero velocity closed about it, it cannot escape, but will always remain attached to the planet, and its radius vector will have a superior limit. How the moon and other satellites came within these closed regions Dr. Hill did not inquire, and subsequent investigators appear to have supposed that as these bodies cannot now escape from their planets, so also conversely they cannot have come in from a remote distance, but must have originated where they now are. This is the view put forth by Moulton in his discussion of Prof. W. H. Pickering's suggestion that Phoebe had been captured by Saturn (cf. *Astrophysical Journal*, October, 1905); but such reasoning is easily shown to be erroneous by the following considerations:

4. Jacobi's integral, as originally given by him, is based on the differential equations for unrestricted motion in empty space, and no account is taken of the additional terms which must be added to the differential equation of the motion of the sun, planet, and particle when the motion is conditioned by the introduction of a nebular resisting medium, such as existed in the early history of our system, and is now observed to be widely diffused throughout nature. Jacobi's original integral, therefore, requires the addition of a secular term to represent the actual movement of a sun, planet, and particle; and the complete expression for any particle whose co-ordinates are x, y, z , becomes

$$x^2 + y^2 + \frac{2(1-\mu)}{\sqrt{(x-x_1)^2 + y^2 + z^2}} + \frac{2\mu}{\sqrt{(x-x_2)^2 + y^2 + z^2}} - C + at \quad (1)$$

The secular term at makes the constant increase with the time.

5. Now the surfaces of zero relative velocity, which define the closed spaces about the planets, have larger values of C the nearer we approach to the sun or planet. This is easily seen in the accompanying plate from Darwin's celebrated memoir on Periodic Orbits ("Acta Mathematica," vol. xxi). When the particle or satellite revolves against resistance, therefore, the second member of 1 increases, and there is a secular shrinkage of the surface of zero relative velocity. Accordingly the particle drops down nearer and nearer these centers, and the surface finally becomes closed, leaving it no longer free to move about both bodies, in the hourglass-shaped space, as formerly, but restricted to the sphere of influence controlled by the sun or planet individually as the case may be. The particle which once revolved about both the sun and planet can no longer do so, but becomes an inferior planet or a satellite of the planet.

6. This is how all the satellites of the solar system were captured. At first they moved about the sun, and could pass from the sun's to the planet's domain, through the neck of the hourglass-shaped space connecting the two spheres of influence. When the neck is narrow, Darwin says that a particle which passes from the sun's to the planet's control may revolve about it hundreds of times, before quitting the planet's sphere to return again to the sun's control. And if resistance is meanwhile encountered, so that the neck of the surface of zero velocity becomes closed, it is clear that the particle never will quit the sphere of the planet's control, but will abide there permanently as a satellite.

7. Thus it incontestably follows that the satellites of Jupiter, Saturn, and other planets formerly moved about the sun, and have had their orbits reduced in size and rounded up under the secular action of the resisting medium formerly pervading our solar system. Satellites may cross over the line SJ before coming completely under the planet's control, in which case they will move retrograde. In such cases the neck connecting the two spaces is extremely narrow. But as the neck usually is not so narrow as to produce crossing satellites, most of them naturally move direct, in accordance with observation. This is the reason also why the planets have direct rotations on their axes. Planets have in no case been inverted, as some have recently supposed, in order to account for the retrograde motion of the satellites of Jupiter and Saturn.

8. In the case of the terrestrial moon it is shown that the earth simply captured one of the twenty-seven million such planets which went to form the sun's immense mass. The moon came to us from the depths of space, and never was a part of the earth, as has long been supposed. Prof. Sir G. H. Darwin's celebrated work of 1879 is shown to be based on chance coincidences, and not actual physical history. All the details of the lunar terrestrial system are known to accord with the theory that the moon is a captured planet. a. It is shown by rigorous calculation from the theory of probability that the chances are infinity to one that the moon was captured like the other satellites. b. It is likewise shown that the probability is infinity to one that the earth could not have rotated with sufficient rapidity to detach the moon. As the theoretical possibility of the capture of the moon is beyond doubt, it is therefore certain that it actually occurred.

9. The earth never rotated much, if any, faster than at present, and is a much better time-keeper than has been supposed heretofore. It never had a high degree of oblateness, and changes in rotation have had little if any effect on the events contemplated in geological history.

10. As the moon came to us from celestial space, it was, when first captured, at something like double its present distance; but has since gradually neared the earth. The orbits of the other satellites have been reduced in size and made more circular by the secular