THE BIRTH OF THE EARTH.

THE nature of the earth at its surface is apparent to us, and we may make direct physical and geological observations of the conditions in the surface layers.

Mines and bores have penetrated to a certain depth, and natural cracks and upheavals show us something of the nature of the disturbed crust : but the greatest depth to which a test bore has been taken is eleven thousand feet. Whilst that seems a very great depth, we must not forget that it has only stabbed to one-four-hundredth of the total distance to the centre of the earth, and that only at one place.

For further information geophysicists are dependent on the manner of the formation of the world and the observed nature of its parent, or on examinations of the records of naturally created and transmitted earthquake shocks. By a section of applied geophysics known as geophysical prospecting he may acquire a considerable amount of information as to the physical nature and disposition of materials in the earth's crust down to a depth of a few thousand feet.

A great amount of our modern theory as to the nature of the world depends, then, on the theory of the method of formation.

There seems to be no warrant for regarding our solar system as being composed of "strays" from different places ; it may be agreed that the sun and planets formed at some time a single body, which has since separated out into the main incandescent solar body, and the relatively cold planetary and other bodies circulating about it.

The theory of formation of the solar system which I am accepting for this discussion is the tidal hypothesis due originally to Chamberlain and Moulton of Chicago, and developed by Jeans and Jeffreys of England. Before accepting them, let us look at one earlier theory.

THE THEORY OF LA PLACE.

On the hypothesis originated by La Place the sun and planets were once portion of a highly diffused nebula that extended out to the bounds "beyond the perihilia of the observable comets." La Place himself conceived of the matter as being denser towards the centre of this nebula, which rotated about an axis nearly perpendicular to the plane of the ecliptic, round which it was approximately symmetrically disposed. As the nebula condensed its rotation became faster and faster, because the angular momentum of the system about its axis of rotation remained approximately the same, being unaffected by external torques. Any portion of the nebula would be whirling in a circular path under the balanced force of gravitational attraction inwards, and fluid pressure outwards. As the mass contracted, a stage would be reached when the acceleration towards the centre required to hold it together and constrain it to rotate in its approximate circular path would be greater than the gravitational pull available, and the outermost portions would be left behind, rupture taking place. Thus, eventually, unless the nebula had become solid before rupture took place, in which case it would not take place, the nebula would condense to a set of separated rings whirling with different velocities round the central axis. These rings, by some method which has never been satisfactorily explained, must then have condensed to single planets with satellites.

In a modification of this nebular hypothesis slight inequalities of density within the material of the nebula led to the concentration of the nebula into planetary nuclei, round which the other matter condensed.

A simple calculation enables us to examine the present angular momentum of the solar system; if the sun and planets were spread out even to the orbits of Neptune, and the matter were rotating with the angular velocity of the "Neptune ring," its angular momentum would be 600 times the present angular momentum of the system.

The discussion is *not* aided by the recent discovery of the planet Pluto, and a more complete examination of a nebula hypothesis leads us to consider it as quite untenable.

Theories, such as this, of rotational instability have now been discarded for tidal theories.

The Theory of Chamberlin and Moulton.

Tidal theories depend on the approach to the sun of a star much more massive than itself, which produced two great tides on the sun, the peaks being at the points of the sun nearest to and furthest from the star. The distance between passing star and sun decreasing, portion of the gaseous sun was swept from its surface, and condensed to form planets, satellites, *et cetera.*

The planetisimal theory, due to Chamberlin and Moulton, "produced" two filaments projecting from the sun at diametrically opposite points. (Jeans and Jeffreys require only one filament, the furthermost filament being short, sinking back into the sun with the passage of the star away on its course.) In the planetisimal theory the little portions of filament condensed into minute planets, most of which were then swept up by the larger bodies, which thus grew as accumulations of already solidified material. The orbits of the planets were at first highly eccentric, the resistance offered to their movement through the swarms of planetisimals slowing them into their present orbits as they grew by "sweeping the heavens."

Geophysicists such as Jeffreys do not consider that the masses of the planets can have increased by any considerable fraction of themselves since they were formed; "the planetisimals would have vaporised by collision among themselves before they would have had time to affect the eccentricities of the planetary orbits appreciably."

In Chamberlin's theory (this same "growth by accretion" theory) the earth has always been solid. He explained mountain building in terms of the compression produced by the collection of solids on the surface, thus producing crumbling. He was therefore opposed to the view that mountains were formed by crumpling due to thermal contraction. An examination of the compression produced by accretion loading, even if the planet increased in size enormously by this means (which is not possible) shows that compressions produced would not be of the order to produce mountain building to the extent required.

THE THEORY OF JEANS AND JEFFREYS.

In Jeans' theory, for the presentation of which he was awarded the Adams Prize of the University of Cambridge in 1917, he examines slow and sudden "encounters" between the sun and a passing star. In his original theory his sun was occupying the space at least out to the orbit of Neptune; he required, as he thought, a sun of that size so as to make the stellar encounter a probability. Since then he has accepted the modification produced by Jeffreys that the sun was at the time of rupture practically as it is today.

The equipotential surfaces of the sun are easily calculated; in a *slow* tidal encounter, approximate equilibrium is attained, the matter being drawn out into a peak towards the star and swinging round after it as it passes. Jeffreys considers such a slow tidal encounter dynamically impossible. In the case of a *transitory* encounter, the effect would be as though a velocity were suddenly imparted to the envelope of the sun, the peak forming and being flung out into space. In this case the star would have passed and gone too rapidly for planets to form and swing into orbits round the sun; the matter would drop back into the sun again. It is probable that this tidal encounter was really intermediate between these two, so that a filament was drawn out into space, and curved and swung in the direction of the departing star. The matter was matter as such, in gaseous form, as it now exists on the surface of the sun, where we can examine it spectroscopically. This is based upon the reasoning that the time which has elapsed since the birth of the world is such a short time in the total life of the sun that it was practically in its present state.

The effect of an approach intermediate between slow and transitory would be that a filament of solar gas would be drawn out into space towards, and following, the passing star. As the star passed on, the envelope would collapse back into its previous dimensions, and the filament would tend to fall back into it; but having been given a tangential velocity as well as a radial velocity, much of it would "miss" the sun on its return and oscillate in an elliptical orbit around it.

The filament having been formed, presumably fairly uniformly dense, the condensation of planets may have proceeded in several ways. Remember that this material was a gas, surrounded by a vacuum, and that a gas spreads out into a vacuum; there would also be a disruptive action due to the sun itself.

In the sun the lightest materials would have been in the outer layers, which would be the first ejected, and hence the least dense material would have been the end of the filament farthest from the earth. The very lightest material may have escaped from our solar system altogether. The next lightest material condensed to form the outer planets, which are of low density. The filament would tend to be cigar-shaped on detachment, fat in the middle and thinned out to either end.

The process of condensation is important. The mass per unit of length of the filament was probably a maximum at the centre; probably as the material was drawn out, gravitational effects within the gas caused the filament to draw together into portions of greater density, which thus collected surrounding gases to them, and the gaseous planets were formed. Where the masses were great, the planets were able to continue to hold to themselves the gases of least density by gravitational attraction, so that the greater planets have held probably all the material which they originally collected, whilst the smallest planets have already lost a lot of material which did not condense to the liquid and then to solid form.

It is easy to calculate, on a gas condensation theory, the minimum size of a planet which could be formed by condensation. The lower limit is 2,000 kilometres radius.

The mutual gravitation of the parts of a large "collected" planet would hold it together in its gaseous form, whilst radiation from the surface would gradually liquefy it. In the case of the smaller planets, the outer surrounding gases would spread out into space, cooling by radiation and adiabatic expansion as they did so. It would be a race between expansion and cooling to the liquid form. Drops would form in the outer surface of the gas; these would fall in through the *hotter* gases towards the centre, which they (or, rather, subsequent drops) would eventually reach in the liquid state. The materials to condense first will be those of high temperature of vaporisation, and we know that the mean density of the earth is about five and a half, compared with the two and a half mean for the geological crust.

Evidence of earthquake transmission through great depths leads, apparently, to the interesting conclusion that the centre of the earth is a nickel-iron mixture, occupying about half the radius. The radius of the earth is some 4,000 miles, and the radius of this dense core is 2,000 miles; moreover, it behaves towards transmitted waves as if it had a zero rigidity—it acts as a fluid.

A brief summary such as this is unconvincing. Senior students in geology and physics will find it interesting to borrow Jeffreys' "The Earth" (2nd edition) and to read the simpler expositions therein, remembering at the same time that these are stimulating theories which are capable of alteration or replacement as we learn more.

A WITCH'S BREW PREPARED BY A LEAVING CERTIFICATE CANDIDATE: PHYSICS, 1933.

Q.: ". . . Describe and discuss two phenomena which may be explained in terms of surface tension."

A.: "Surface tension is shown by soup containing fat globules, water spiders, floating needles, *etc.*"

URGENT

AUSTRALASIAN MEDICAL PUBLISHING
COMPANY, LIMITED
Seamer Street, Glebe, N.S.W.

I enclose herewith {*Postal Note* / *Stamps*} *for one shilling, being my subscription for Volume I of the journal* ENVIRONMENT, *post paid.*

Will you please forward me also..

copies of issue No. 2, for sale to students; I will forward the receipts, at threepence per copy, on collection.

Name..

School..

Subjects..

A limited number of issue No. 1 are available at *sixpence* a copy. Please order immediately if required to complete sets, which will be valuable for reference.

(Please do not send more than 1/- by stamps.)

AUSTRALASIAN MEDICAL PUBLISHING
COMPANY, LIMITED,
Seamer Street, Glebe, N.S.W.