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THE STORY OF COSMOLOGICAL THEORY[1]

I

IT may be that primitive man felt none of the

> Blank misgivings of a creature
> Moving about in worlds not realized.

For him, perhaps it was enough to taste the joy of living, to watch the rising and the setting of the sun, to gaze upon the mountain, the river and the restless sea, and never to ask himself the question "what is this world in which I live, and how did it come into being?" But this problem eventually presented itself, for there has been implanted within the human breast that which distinguishes its possessor from the beasts which perish, the passion for knowledge, the deep longing for

> Authentic tidings of invisible things,
> Of ebb and flow and ever-during power:
> And central peace subsisting at the heart
> Of endless agitation.

And so there arose those questions about himself, about the visible universe in which he dwelt, and that invisible world about which he dreamed, from which have sprung all that we now call science and philosophy.

How slow and laborious have been the steps by which knowledge has been attained, and how childish and even grotesque the answers to these first questionings. But to have any theory at all for the first causes of things is very much better than to have none, and these crude products of primitive man, and the refined deductions of the modern scientist are the same at

[1] Opening lecture of the year, delivered at the Autumn Convocation, McMaster University, Toronto.

heart. Alike they seek to deduce from known facts the underlying principles of nature. If the modern hypothesis appears to lie much nearer to the truth, it is because the facts upon which it is based are more numerous and more completely verified. Nor should we forget that it has had the advantage of a long series of tentative explanations, which it now replaces. All our advances have been made over the remains of discarded theories.

It is here proposed to trace in outline the history of the theories which from time to time have been suggested to account for the way in which the earth was formed. It will be seen that we have here three stages in human intellectual development. In the first the world was conceived to be due to the literal handicraft of a beast, a demigod or a divinity. In the second it was realized that a nobler origin must be sought, but methods of scientific criticism had not been perfected sufficiently to put the theories to the test. In the third, every one had to be submitted to the most rigid dynamical analysis.

II

In order that these primitive theories may have an unprejudiced hearing it is well for us to try and put ourselves in the place of their authors. Let us view the world as seen through the eyes of the ancients.

At the time of the dawn of consciousness, man found himself on what appeared to be a flat and circular earth. As he extended his wanderings this way and that, although great ranges of mountains occasionally stood in his way, they could eventually be crossed, but sooner or later he seemed always to come to the shores of the impassable sea. So he concluded that the disc-shaped land was completely surrounded by the ocean, which flowed like a mighty river around the earth. Above him was a great dome, forming a lid to it all. This was evidently of solid material, glass or some metal, possibly brass. Some claimed that it must be transparent, others, that it was perforated by windows, for at night the light of the celestial regions shone through, and he called these bright objects stars. The Egyptians had a slightly different explanation, for, according to them, the stars were lamps hanging down from the ceiling of the world on the end of chains. Over this dome he saw passing, with wonderful regularity, various bright objects, notably the sun, and he soon observed, in addition to its regularity, that it had a very rapid motion, for it came up from beyond the River Oceanus, probably through a great door, in the morning, and in about twelve hours had crossed the dome of the heavens and was at the door of the evening, ready for its return journey through the upper world down to the gate of the morning once more. This rapid journey, in the days before steam or gasoline, could be explained only by the use of swift animals, and what animals are so swift as horses.

Above the dome of the heavens there seemed to be another ocean, for ever and again the roof leaked and showers of rain fell upon the earth. It was evident also that there must be beings there who controlled the activities of nature, and probably they could occasionally climb down by way of the sides of high mountains, whose tops, inaccessible to man, undoubtedly touched the sky, and indeed, probably helped to support it.

Now all the mysterious and terrifying forces of nature were to be explained in a perfectly naturalistic way, by the intervention of these beings from the upper world. Was the oak under which our forefather had taken refuge in a storm, shattered by the lightning, it was because one of the gods had hurled a flaming dart.

Was he unfortunate enough to receive into his veins the poison of malaria, it was because an evil spirit had entered into him and had to be induced to come out by a bribe, or driven out by the use of mystic combinations of words which were calculated to cast a spell over it. So when the author of creation was thought of it was in the form of an animal like those he hunted, but much bigger. A turtle, swimming in the primeval ocean, dives down, as he had often seen it, and, coming up, bears upon its back some of the mud from the bottom, and on this, trees grow and living creatures move and among them all, himself. At times the load grows heavy, and the turtle moves, and the earth quakes, and perhaps some day the whole will slip again beneath the waves.

Or, again, a number of animals have escaped the destruction of a previous earth on a raft. They float for many days upon the face of the waters and find no place for the soles of their feet to rest. They take turns at diving in order to bring up some earth from the bottom, but it is not until several of them had essayed the task that a grain of sand is recovered. From this they mold the new earth, and then disembark and a new era commences.

These simple theriomorphic tales are found among the less advanced races. In the minds of those who had observed more carefully, and thought more deeply, profounder ideas began to prevail. To the thinker of Neolithic times, as indeed to him of to-day, one of the most wonderful things in nature is an egg. Within this thing, apparently so simple in its constitution, there is developed, and that in the course of a very short time, all the complexity of structure of reptile or bird. Perhaps even he dimly realized that all things living proceed from an egg. It was evident also that the order of nature is from the simple to the complex, and the world, in its marvelous complexity, is no doubt, he thought, a living thing. What would be more natural, then, than that the world itself is the final product of the development of an egg? This theory is found again and again in the mythologies of ancient races, persisting even among the stories of a nobler cosmogony. Thus in the Book of Manu, in Indian Classics, we read "the self-existing lord, with a thought, created the waters, and deposited in them a seed which became a golden egg, in which egg he himself is born as Brahma, the progenitor of the world."

III

We have now come to the stage in human development when it was no longer necessary to explain the origin of the world in terms of beasts or demigods. A new theory now had to be formulated in the light of increased knowledge and broader mental grasp. To some it may have appeared that things had always existed as they are, but the philosophical necessity for an explanation of origins early impressed itself upon the minds of the Greeks, who were the first to devote themselves to such speculations.

Two alternatives formed the foundations for the theories of two opposing schools of thought, the one of monism, the other of dualism. To Leucippus and Democritus and their disciples the world appeared to have been the result of a fortuitous concourse of atoms. Behind it all they saw no plan, no intelligence. This was the underlying concept of the great poem "De Rerum Natura" of the Latin poet Lucretius, who lived in the first century B.C. He tells us:

> Nam certe neque concilio primordia rerum
> ordine se suo quaeque sagaci mente locarunt
> (5: 419),

which may be translated:

For verily not by design did the first-

beginnings of things station themselves each in its right place by keen intelligence.

To Plato and his school, on the other hand, the orderly course of nature can be explained only as the incarnation of a divine plan. So he conceived of the universe before the creation as consisting, on the one hand, of chaos and disorder, matter without plan or qualities; on the other hand, of the eternal plan or soul of the world existing in the mind of God. Then the creator, taking this inert nothingness, impressed upon it the eternal idea and the whole becomes an organic unity.

Thus the universe was created, unchanging, unchangeable, and this idea, as modified by Aristotle, became the current coin of the intellectual world. Nearly twenty centuries passed before the next advance came with the realization that the world did not spring into existence full grown, but that its present state is the result of a long series of changes.

IV

Before this idea of progressive development could be attained, it was necessary that certain hoary fallacies should be cast aside and correct notions substituted. Until it was realized that the earth and the other celestial bodies are spheres, and that the sun, and not the earth is the center of our own system, the progress of astronomy and cosmology were slow and imperfect. But these were concepts of very gradual growth.

In the early part of the fifth century B.C., Parmenides, of Elea, wrote a short poem on Nature, of which we still possess a few fragments. In this he refers to the spherical form of the earth, a truth which he appears to have been the first of all mankind to enunciate. Around the earth as a center he conceived a series of concentric spheres on which were fixed the heavenly bodies, an idea which was not without its supporters during the following two thousand years. A little later it seems to have been taught by Pythagoras. From it his disciples and successors framed their interesting theory of the Cosmos, which was believed to consist of the "central fire," the "hearth of the universe," round which were ten concentric spheres. There must be ten, for the system is perfect, and according to their idea, ten is the number of perfection. These spheres bear in succession the fixed stars, the five planets, the sun, the moon, the earth and another celestial body, which they called the "antichthon" and which served as a screen between the earth and the central fire. Around this blazing pivot revolved the earth once in 24 hours, always facing outwards, and so bringing into view the various parts of the heavens in succession. Consequently the back of the earth must always be dark. Therefore, if one were to travel past India, there he would find a land of perpetual twilight, where neither the blessed light of the sun nor the rays from the central fire could ever penetrate.

The spherical form of the earth was subsequently taught by Plato, who, like all that followed for two thousand years, placed it in the center of the universe, and finally, by Aristotle, who became, until the Renaissance, the dominating figure in European thought.

But the development of correct cosmological ideas was not destined to continue uninterruptedly. In 389 the great library of Alexandria was destroyed. Shortly after came the fall of the Western Empire and the long, dark night of the middle ages set in. Most of the gains which science had made during the previous centuries were forgotten, and the Church, which then became the custodian of all that was thought worthy of preservation, set its face firmly

against the learning of the pagan Greeks. A new theory of the universe, according to a plan which would follow their interpretation of the Holy Scriptures, consequently appeared to be a desideratum. The great task of inventing this fell to Cosmas, surnamed, on account of his extensive travels, Indicopleustes, the Indian voyager. According to him, since the Epistle to the Hebrews expressly declares that the inner tabernacle was a pattern of the Kingdom of Heaven, it follows that, if we would understand the construction of the universe, we can find it epitomized in the description of its antetype in the Book of Exodus. The table of shewbread with its wavy border represents the earth surrounded by the ocean. Therefore the earth is rectangular, twice as long as it is broad, its longer dimension extending east and west. Beyond the ocean, as is clearly proved by the existence of an outer border to the table, lies another land where is situated the earthly paradise. That other was the home of mankind until the flood, and then Noah sailed across. But since that day the return journey has become impossible, owing to the tempestuous weather which ever prevails upon the ocean. We who actually live in trans-oceanic lands may be permitted to disagree on some points with the learned theologian, for we have found neither the terrestrial paradise nor the tree of life which it contained. At the edges of this other earth were erected the walls of heaven topped by a roof shaped like half a cylinder. But it is a two-storied building, is the universe, and the firmament forms the division which is at once the roof of the world and the floor of heaven. Above the firmament are the abodes of the blest.

The motions of the heavenly bodies are to be explained by the activities of the angels. They carry the stars in orderly succession over the heavens. They also carry the sun. Now the northern part of the earth is very high, in fact rising to an exceeding lofty mountain, and on their return journeys the sun by night and the stars and moon by day are borne by the angelic host behind the mountain and so are not seen. In winter they go with the sun near the base, and night is long; in summer near the top and night is short.

This famous system of Cosmas, the crowning absurdity of medieval science, the culminating flower from seeds of wilful ignorance, was indeed the climax of the anti-scientific spirit. After this the old ideas of the constitution of the universe once more began to be critically studied, and once more the wheels of progress, for many centuries almost stationary, began to move.

For the first hypothesis of a universe which revolves around the sun, we must go back many ages. In the third century before Christ, Aristarchus of Samos first conceived this great truth. How he arrived at this he has left us no explanation. A century later a Babylonian named Seleukis reaffirmed the diurnal motion of the earth, but for the most part, for 1,700 years, the voice of Aristarchus was as of one crying in the wilderness.

Then came Copernicus, one of the world's great geniuses. In the work of his predecessors one must search diligently to find the grain of truth among much chaff, but with him the system of the universe was revealed with great clearness. This, substantiated by the work of Kepler, of Galileo and of Newton, has formed the basis of all subsequent progress.

V

When once the nature of the sun had begun to be understood, and the stars were seen to be, like it, fiery orbs, it was natural that men should begin to think that the earth itself, now seemingly cold, might

have been a fiery mass. This idea was first suggested by Descartes in his "Principia Philosophiæ," published in 1644. According to him, the earth, like every other celestial body, was formed by the aggregation of primitive particles of matter which have an inherent whirling motion. The resultant sphere, after it has changed from the gaseous to the molten condition, cools and becomes covered by a solid crust. But the central portion still retains its hot and plastic condition, which is manifested by the phenomena of mountain-building and vulcanism.

Leibnitz, thirty-six years after, in his "Protogœa," which, however, was not published until after his death, followed an almost identical hypothesis, conceiving the earth to have been built up of an aggregation of whirling ultimate elements or "monads" of matter. But while Descartes looked upon the motion as being due to the momentum supposed to be present in constant amount in the universe, Leibnitz believed it to be due to the force which accompanied the separation of light from darkness.

Later this doctrine was carried a step farther by the philosopher Kant, and finally by Laplace in his theory so modestly put forward, which has since become so famous under the name of "the Nebular Hypothesis."

Briefly stated this hypothesis predicates the origin of our solar system in a great fiery mass of incandescent vapor, similar to the nebulæ, which are among the most wonderful objects revealed to us by the telescope. The parent nebula of our system must have extended far past the present orbit of the outermost planet, Neptune, then undiscovered. In order to fill this space the matter available must have been spread out extraordinarily thin; in fact, the density would be one millionth of that of the air we breathe. The whole was subject to a rotary motion. As time passed, heat was radiated into space, and, as the tenuity was maintained by heat, the mass became cooler and denser. Particles on the circumference would thus steadily move closer in to the center. Now the velocity of any such particle would remain unchanged, while the distance it would have to travel in order to complete the journey around the center, would steadily grow less. It follows that it would be whirling around the axis at an ever-increasing rate, and consequently, with an ever-increasing tendency to fly off into space. At the same time the pull of gravity, since the particle is closer to the center, is constantly growing greater. It is then subject to two steadily increasing forces, one of which tends to throw it off, the other to drag it down. A time will come when these two forces will just balance and the particle will go up neither nor down, but remain revolving in an orbit. The total result of this on all the particles of the outer zone would be to leave them in the form of a ring of gas. Similarly, the same process would be followed in the case of another zone, until the whole would resolve itself into a central spherical nebula surrounded by a series of rings. Each ring in turn would soon break, and the gas of which it was composed would come together in a revolving sphere, which might give rise to other rings. The system is constantly cooling, and the spheres of gas, finally solidifying, give rise to the planets and satellites.

The simplicity and grandeur of this theory fire the imagination. It is no wonder that it took firm root. For several generations it was received without reservation. Gradually, however, serious defects began to be seen. For instance, if we calculate the rate of motion of the molecules of such a system, the temperature and rate of rotation of the whole being

known, it can be proved that this motion would be so great that the force of gravity, even of so great a mass, could not prevent them from flying off into space and so being lost.

Again, it can be calculated from the facts at our disposal, where the rings would be left by such a cooling nebula. It is then found that the first ring, instead of being in the position of the present orbit of Neptune, would be inside the orbit of the inmost planet, Mercury. Where fact and theory do not agree, so much the worse for theory.

These are typical of the numerous and insuperable objections to the acceptance of the hypothesis. Within the last few years, the belief has been gaining ground among astronomers and geologists that this theory, so long the accepted one, must in its turn be discarded.

The cogency of the difficulties which have presented themselves whenever the theory of Laplace has been critically studied cleared the way for the meteoritic theory as presented by Lockyer and modified by Darwin. But here again the objections raised are so many and so reasonable that it stands on no surer a foundation than its predecessor.

Of recent years, the Planetesimal Theory of Chamberlin has been gaining ever-increasing support. Like the authors of preceding theories, he scanned the heavens for facts which might have a bearing upon the problem in hand. He saw, like them, the brilliant masses of "star dust" which we call nebulæ, but he saw also the importance of the fact that there are two distinct kinds of nebulæ. One kind, sometimes spherical, sometimes irregular in shape, is composed of incandescent gas; the other, consisting of two tightly coiled spiral arms, is evidently made up of solid particles. In the latter only do we find indications of the important metallic elements which occur in the earth.

This suggested to him that the parent nebula of our solar system was probably one of the spiral type, and his first problem was to account for the origin of such a nebula. An occurrence, famous in the history of astronomy, has an important bearing upon this. Nearly 350 years ago (November, 1572), Tycho Brahe, the famous Danish astronomer, was very much astonished to observe a new star in the constellation Cassiopeia. An hour before he had scanned that part of the heavens and saw nothing, and when he looked again there it stood, a star of the first magnitude. From night to night it grew in magnificence, surpassing in turn the fixed stars, the planets, even Venus at her brightest, until it could be seen at noonday. It had now become the most glorious and brilliant orb in the heavens, giving, it has been calculated, 100,000 times as much light as our sun. Then this strange luminary slowly faded away, nightly becoming less brilliant, until, after the lapse of 17 months, it sank into final darkness.

How is this astonishing phenomenon to be explained? The general belief is that it was probably due to the collision of two great celestial bodies. Their energy of motion was changed into molecular energy, and the elements melted with fervent heat. So hot indeed did they become, that a great cloud of incandescent gas was the result, whose molecules were moving at such rapid rates that they were whirled away into space and so disappeared. Other stars of this kind have frequently been observed since then, but never has one so brilliant been recorded.

Now it may be that we have here a typical example of the formation of a gaseous nebula, though but a temporary one. Had the impact been less violent it might have been permanent. But what

would have been the result if the bodies in question had not actually collided, but had passed very close to one another? It can be demonstrated mathematically that such an approach would entail the formation of two prominences, on each body one at the point of least distance apart, and one diametrically opposite. If the approach be close enough, these prominences may be drawn out into the form of two long arms composed of discrete particles. As these bodies pass, each, by the pull of its gravity, will communicate to the other a rotatory motion which will result in the coiling of the arms. These will be composed of large numbers of comparatively small particles, each of which is revolving in a regular orbit around the central nucleus of the system. These particles, resembling in their constitution meteorites, have been named planetesimals, and hence the name of the hypothesis.

Now, while the whole is rotating and has the form of a spiral swarm, the tendency will be for the planetesimals to come together and form a series of nuclei in the arms, which, as they grow by accretion, become solidified and form the planets. In our present stage, most of them have been gathered in. A few are still falling as meteors, but the addition from this source to the size of the earth is quite insignificant.

This is the famous Planetesimal Theory. It explains the phenomena better than any other which has yet been suggested. But it may be that this, too, will eventually go the way of past theories, and its place taken by another newer one. It is too much to believe that we have now reached finality, and that our hypothesis outlines the actual physical facts of our earth's history.

Certain recent observations already suggest a somewhat different organization of the universe than that on which this theory is based. It has been pointed out by Campbell that while the gaseous nebulæ are to be found mainly in the direction of the Milky Way, the spiral nebulæ are never seen in these parts of the heavens but are numerous in directions at right angles. Now the stellar system is looked upon as being of a discoidal shape, and what we call the Milky Way is merely the direction of greatest depth and consequently of closest distribution of the stars. It follows that at right angles to this we look through the stellar system and out into infinite space, and it may be that the spiral nebulæ which are to be seen in these directions are not within our stellar system at all. Measurements of their motion towards and away from us indicate that they are moving at very rapid rates, probably as great as 500 miles per second, a very much greater speed than that of any known star. And yet, when their relative positions in space are compared with those they occupied fifteen years ago, scarcely any change can be observed. That is to say, the nebulæ are either all moving directly towards or away from the earth, which is incredible, or, although they have a lateral motion of enormous rapidity, they are so far away that the distance traveled in fifteen years is imperceptible to us. How great their distances may be we can not comprehend, even though it were expressed in figures. From here to the utmost confines of our stellar system is estimated as being of the order of 15,000 light years, that is the distance light will travel, going at the rate of 186,400 miles per second, in 15,000 years. And if this theory be correct, the nebulæ are so far away that, though as large probably as our stellar system, they seem to us scarcely larger than one of the planets. We may therefore look upon them as other stellar systems like our own. And if there be on a planet within one of these spirals, astron-

omers and telescopes such as we have, to them our stellar system would appear as a spiral nebula, a scarcely visible point of light in the starry heavens.

Now Campbell would carry us one step further in our search for the true theory for the origin of the world. At a certain point within the great spiral, a subsidiary whirl was developed within which grew, by the infall of planetesimals, as suggested by Chamberlin, our solar system, including the infinitesimal speck of matter upon which we live our unquiet lives.

VI

I have now traced the growth of man's idea of the origin of the planet on which he lives from the crude cosmogony of primitive ages up to the scientific theories of the twentieth century. Notwithstanding periods of intellectual stagnation and even of retrogression, this represents a continuous broadening of his grasp upon the realities of his physical environment. But we have not yet attained finality. The great mysteries of knowledge are as yet unfathomed.

But one thing we have learned.

> The spirit of eternal change,
> Which is the soul of nature

is all pervading. What we see is but an evanescent phase in an endless series of changes. There was a time when they did not exist; there will come a day when the thousands of fiery suns which we see in the heavens to-night will, each one, have cooled down to darkness and death. To our finite minds the life of a sun, measured as it must be by hundreds of millions of years, seems inconceivably long, but to "the spectator of all time and all existence" to borrow Plato's noble expression, it is but as a momentary flash. Now although it is believed that there are a great many dark bodies in the heavens, most of the stars are still alight. Together they came into being, together their fires will disappear.

> They shall all grow old as doth a garment, and as a vesture shalt Thou fold them up.

WILLIAM HARVEY MCNAIRN

WORK OF THE DEPARTMENT OF AGRICULTURE

REVIEWING the progress of the campaigns for increased production to meet war demands and conditions, David F. Houston, Secretary of Agriculture, in his annual report states that the farmers of the nation, patriotically responding to the appeals of agricultural and other agenices, have produced more than 5½ billion bushels of cereal food crops—exceeding by 1,000,000,000 bushels the five-year average for cereals—record crops of Irish potatoes and sweet potatoes, large crops of beans and sugar beets, and an unusually large crop of perishables. Authentic figures for meat, poultry, dairy products, and vegetable oils are not available for 1917, but rough estimates indicate that the quantity for the year is slightly greater than for either 1916 or 1915 and exceeds the five-year average by two or three billion pounds.

It must be borne in mind, however, the secretary says, that the 1917 cereal crops are 199 million bushels below the yield of 1915; that the carry-over of cereals from last year was much below the normal; that the percentage of soft corn of the 1917 crop—which can not be used for food—is unusually high; and that, with the destruction of live stock in Europe and the great demands from there for meats and fats, with consequent greatly increased exports from the country, the supply of meats and fats will not be adequate to meet the domestic needs and those of the nations with which we are cooperating.

"That the farmers of the nation have generously responded to the appeals for increased production, and that much has already been done to insure a large supply of foods and feedstuffs, justifies no let-down in their activities or in those of all agricultural agencies," the secretary says. "On the contrary, even greater efforts must be put forth in the coming