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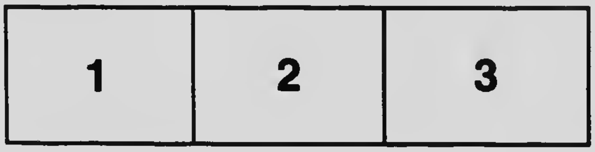
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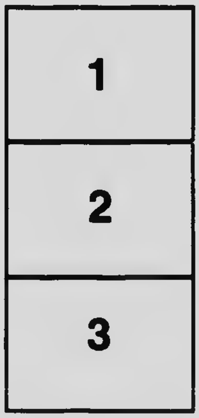
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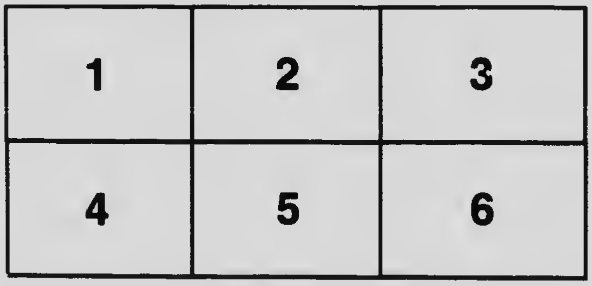
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THE EVOLUTION OF WORLDS

(PRESIDENT'S ADDRESS, ANNUAL MEETING, JANUARY 10, 1911).

BY

ALFRED T. DeLURY, M.A.

TORONTO:
1911

THE EVOLUTION OF WORLDS

By A. T. DeLury

(President's Address, Annual Meeting, January 10, 1911).

IN the growth of science it is a striking fact that the thought and strivings of different ages have been very markedly affected, one might say guided or even controlled, by some outstanding prejudice, conviction or method. Thus in the science which our Society fosters, the assumption that the earth is the centre of the universe held the rein on astronomical activity throughout a long period rooted in an antique past and shading significantly into the age we call modern. So also in the newer age of science heralded by Leonardo da Vinci and Bacon, the distinctive mark is the demand that knowledge of the world of nature must be made to rest on observation and experiment. True, observation and experiment were not new as methods, the great legacy of Greek astronomy standing a monument to the true spirit of scientific enquiry, but now they were formulated and insisted upon as the only final basis and investigation went forward under the new impulse. In our day the great interpretive principle that dominates all science is that implied in the theory of evolution. As in the case of the directing method of modern science, the idea is not new. The search for beginnings and causes — the *motif* of the great epic of science, the *De Rerum Natura* of Lucretius, he who claims Virgil's noble line,

Felix qui potuit rerum cognoscere causas

—— is as old as the spirit of enquiry, and there is scarcely any science that has not had to consider origins and developments. Yet it was only on the appearance in 1859 of Darwin's great work on organic evolution that the concept assumed its supreme position. It became almost at once the august setting for all science. In all spheres of human thought and interest, facts were now interpreted in terms of it, and conduct regulated in accordance with its supposed dictates. To such an extent, and it may be said with such slight resistance, has the principle of evolution become a condition of our thinking that, in many sciences, it is with difficulty we appreciate the position and understand the language of the leaders of thought of a century ago. It is, as it were, the consort of the observational and experimental method in science, and, like it, cannot be thought of as ceasing to have an increasing value, the growth of scientific knowledge being itself a phase of the all-embracing evolution of things.

In the paper of this evening, we are to consider the more striking evidences of development in that vast extent of time and space which is regarded as the domain of astronomy. Here as in other sciences — if we are not insisting too much on this circumstance — the idea of evolution is not new. Passing over not a few earlier and worthy attempts to account for the present order of things with and about us — our world, and those bodies the moon, the sun, the planets to which our world is "neighbor and near-bred" — we may cite the bold and harmonising hypothesis of Laplace, with which should be associated also the names of Wright and Kant, though their speculations were not known to Laplace. This Nebular Hypothesis or Theory, contemplated a vast nebula occupying a space greater than that whose limits are suggested by the orbit of the outermost planet. This nebula, through rotation, and contraction from the emission of heat, under the operation of dynamical laws, was condensed and moulded into the bodies that make up the solar system as it is to-day. If some bold theorist allowed his imagination to see like origins for individual stars and to assign to them unseen similar planetary families, or to group the stars into ever-widening analogous systems, the children of vast parent nebulæ, it was permitted him by a license kindred to that allowed the poet. The attitude of positive science probably found expression in the words of Comte :

"It may be admitted that we have a right to speculate, with some hope of success, on the formation of the solar system of which we are a part, for it presents many phenomena perfectly understood and, perhaps, capable of affording decisive testimony in regard to its veritable origin. But what rational basis have we for speculations on the formation of suns themselves? How by reasoning on phenomena can we confirm or invalidate an hypothesis of cosmogony when there is, indeed, not a single phenomenon pertaining thereto, explained or explainable?"

A new era dawned with the discovery by Kirchhoff of the significance of the lines in the solar spectrum, and it is a memorable coincidence that this discovery which was to afford a sure foundation for the theory of stellar evolution was given to the world in the year in which appeared Darwin's immortal work. It had long been known that a ray of sunlight when passed through a prism is resolved into a stream of divergent rays of different colors, producing on a screen a band in which is a succession of colors such as appears in the rainbow. This band is called the solar spectrum. It had also been known that the band is not continuous, as was at first supposed, but broken by almost countless fine lines parallel to one another and to what we may call the separations of the colors. More recent investigations had shewn that the light from an incandescent body yields a continuous spectrum, while the light from a glowing gas gives a spectrum consisting of one or more bright lines of a color that assigns to them a definite place in the spectrum band—a place characteristic of the particular gas. For example the spectrum of glowing hydrogen is an aggregate made up of a bright line in the red, a bright line in the green and certain others, the spectrum of sodium vapor an aggregate of a double bright line in the yellow and certain others, and the spectrum of iron vapor an aggregate of a great number of bright lines the most striking being a double line in the green. Kirchhoff found that if the light from an incandescent base or background is made to pass through a glowing gas, which of itself would yield certain bright lines, there appear in the spectrum band dark lines in the places corresponding to the places occupied by the bright lines proper to that gas. Thus the dark lines in the solar spectrum came to admit interpretation and to indicate the presence in the sun's atmosphere of materials such as exist on the earth. Indeed unidentified lines foreshadowed the discovery on the earth of elements not then known. Soon after, Huggins, Angström, Rutherfurd, Secchi, Vogel, to mention only a few of the more distinguished workers in this field, devised and perfected means for examining the light from individual stars. Their labors revealed the fact that the remote stars are essentially as our sun, — bodies with an incandescent photosphere surrounded by glowing gases which, affecting the emerging rays of light, disclose the presence in these orbs of elements whose characteristic lines are known, and the existence of which in the sun had already been shewn. Thus, while variety ever presented itself, there could no longer be any doubt of the unity — not the sameness — of constitution of the sun and the distant stars.

In 1864, Huggins succeeded in obtaining the spectrum of a nebula, one of those distant and mysterious appearances that had claimed so much of the time and thought and speculation of Sir William Herschel. I cannot do better than quote from Huggins's account of the discovery — an account written in 1897, in which he quotes from his statement at the time when success waited on his efforts:

"On the evening of August 29, 1864, I directed the telescope for the first time to a planetary nebula in Draco. The reader may now be able to picture to himself, to some extent, the feeling of excited suspense, mingled with a de[illegible] of awe, with which after a few moments of hesitation I put my eye to the spectroscope. Was I not about to look into a secret place of creation?

"I looked into the spectroscope. No spectrum such as I expected! A single bright line only! At first I suspected some displacement of the prism, and that [illegible]s looking at a reflection of the illuminated slit from one of its faces. This thought was only momentary; then the true interpretation flashed upon me. The light of the nebula was monochromatic, and so, unlike any other light I had as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated in a single bright line, having a width corresponding to the width of the slit and occupying in the instrument a position at that part of the spectrum to which its light belongs in refrangibility. A little closer looking showed two other bright lines on the side towards the blue, all the three lines being separated by intervals relatively dark.

The riddle of the nebula was solved. The answer, which had come to us in the light itself read: Not an aggregation of stars, but a luminous gas. Stars after the order of our sun, and of the brighter st[illegible] would give a different spectrum; the light of this nebula had clearly been em[illegible] by a luminous gas."

I quote further because of the connection, though it is anticipatory:

"With an e[illegible] of caution, [illegible] moment I did not venture to go further than to point out [illegible] we had here [illegible] do with bodies of an order quite different from that of the stars. Further observations soon convinced me that, though the short span of human life is far too minute relatively to cosmical events for us to expect to see in succession any distinct steps in so august a process, the probability is, indeed, overwhelming in favor of an evolution in the past, and still going on, of the heavenly hosts. A time surely existed when the matter now condensed in into the sun and planets filled the whole space occupied by the solar system, in the condition of a gas, which then appeared as a glowing nebula, after the order it may be of some now existing in the heavens. There remained no room for doubt that the nebulæ, which our telescopes reveal to us, are the early stages of long processions of cosmical events, which correspond broadly to those required by the nebular hypothesis in one or other of its forms."

The nebulæ were thus given a distinct status among the dwellers in outer space. They are tenuous bodies of glowing gas. The remakable line first noted by Huggins is that of an element peculiar to nebulæ and named nebulium. The other lines indicate the presence of hydrogen and helium.

In the years that followed came great advances in instrumental appliances. The spectroscope was modified, telescopes of greater power constructed, and the powerful aid of photography enlisted in the service of astronomy. The result has been an organised spectroscopic study of a great number of stars, as well as a careful search of the heavens for nebulæ, notably that by Keeler with the Crossley reflector at the Lick Observatory. It has developed that a great number of the nebulæ, though of an extent and form that differentiate them from stars, yield continuous spectra. A further application of the spectroscope, through the circumstance that an approaching or receding star will show the characteristic lines of the elements displaced to an extent determined by the velocity of approach or recession, has disclosed the fact that many stars are attended by an unseen companion and has thus created an astronomy of the invisible. It is found that, as in the case of visible binaries, the two bodies move round each other in a way in accord with Newton's law of attraction so that with a constitutional unity of the universe we have, at least, one law that seems to be generally valid.

It is in place now to bring together the more essential facts revealed to us by the different methods of investigation; we have

(1) A sun and its attendant planets separated from other celestial objects by distances vast almost beyond comprehension by beings who may speak freely of the ninety or more millions of miles that separate our earth from the sun. This system, independently of the relative motion of its parts, is moving, as a whole, at a great velocity toward the constellation Hercules.

(2) In the vast depth of space is a great wilderness of stars — probably 100,000,000 of magnitude not below 17. These are far from being uniformly distributed throughout the sky, being very markedly condensed towards the Milky Way. The Milky Way itself seems to be a great system with respect to which our solar system occupies a somewhat central position. Round us it seems to coil probably in a widening spiral.

(3) Joint tenants of the deeper space with the stars are the the nebulæ, the number of which estimated by Keeler in his photographic survey is probably 120,000. Comparatively few are gaseous, and these lie near the Milky Way. The stellar nebulæ — those with a distinct nucleus surrounded by nebulous matter — shew a like affinity. The spiral nebulæ constitute the numerous class of nebulæ; they avoid the neighborhood of the Milky

Way and are found with a frequency increasing with the distance from the Milky Way.

We now turn to the evidences of evolution and here the spectroscope must be relied on for assistance. Soon after the spectroscopic examination of the heavenly bodies was entered upon, it became evident that the stars presented a great variety of spectra, so that a classification according to spectra was conceived. A first classification was made by Secchi, and though classes have been multiplied by later workers, the main lines of the older classification have been retained. The truth is that the classes in place of being distinct shade into one another and one is free to draw a line at many places. The different types of spectra point to different surface conditions on the stars and the lines retained or rejected, accentuated or rendered feeble, again admit interpretation. The types of stars according to the classification generally received to-day are:

1. The Sirian Stars which are sub-divided into

(*a*) The Orion Stars. These are purely white. Their spectra show helium and hydrogen lines. Many seem to have nebulous appendages.

(*b*) The true Sirian Stars. These are brilliantly white. The spectrum is strong in the ultra-violet region.

2. The Solar Stars. The light is of a golden tinge, as appears in stars like Capella, Aldebaran and Arcturus. There is a decrease in intensity particulary in the ultra-violet, the violet and the blue region of the spectrum. There is every evidence of an increasing condensation and enhanced absorption. Also there is increasing strength of metallic lines.

3. The Antarean Stars. Antares is a typical star of this class. The light is reddish and the spectrum marked by flutings with the sharp edges lying toward the violet. The hydrogen lines are reduced in intensity, and the bands are due to the presence of oxide of titanium, and eight or nine metals can be recognised by their absorption lines.

4. The Carbon Stars. The light reddish, and the spectrum marked by flutings with the sharp edges lying towards the red. Carbon is present. Bright lines are sometimes seen.

How have the circumstances here briefly sketched been interpreted? Let me quote from Hale, one of the most distinguished of living astronomers—cautiously sane in dealing with the speculative:

"Our problem is like that of one who enters a forest of oaks, and desires to learn through what stages the trees have passed in reaching their present condition. He cannot wait long enough to see a single tree go through its cycle of change. But on the ground he may find acorns, some unbroken and some sprouting, others have given rise to rapidly growing shoots, and saplings are at hand to show the next stage of growth. From saplings to trees is an easy step. Then may be found, in the form of dead limbs and branches, the first evidences of decay: reaching its full in fallen trunks, where the hard wood is wasting to powder.

Scattered over the heavens are millions of stars, each representing a certain degree of development. The cloud form of the nebulæ tells us of stellar origins, the white, yellow and red stars illustrate the rise and decline of stellar life: and the earth itself affords a picture of what may remain after light and heat have been extinguished."

This view of the evolution of worlds, so briefly and simply, yet effectively stated, is accepted very generally by those competent to entertain an opinion in this regard. Nebulæ—some tenuous throughout, others, as the great nebula in Orion, showing well marked nuclei of condensation, others grasping in their vast folds, as in the Pleiades, and regions of the Milky Way, whole systems of well defined stars, all of an extent vast when compared with our solar space—disclose an evolutionary movement into stars. Stars of the earlier types, with their freer light and low specific gravity, confirm their affinity to the nebulæ. Continued condensation builds up stronger atmospheres that tell their story in the spectral lines, until in the Antarean and Carbon Stars the last period of luminous stellar life is reached. In the great advance one cannot demand uniformity of development; rather, on the other hand, diversity of process, often difficult to explain. Yet no longer can the fact of progressive development along certain broad lines be questioned.

The great facts of evolution in regard to the general scheme of things being admitted, the question as to the details of the process in a single system naturally arises, and naturally too we turn to the system which we can examine at closest range, the solar system of which we are a part. No longer do we find a large measure of agreement as to the lines of progress. Certain bolder features call for a quite general assent, but "vergent theories and assumptions soon appear, and where assumptions may be so varied, and final tests of theories can so seldom be made, there is a rich field for conflicting explanations and controvery. An examination of the various proferred theories, particularly when one has to give some account of them, may well call up the opening lines of the great poem of Dante, which itself had as setting the universe as conceived at the time:

> "In the middle of the journey of our life, I (came to) myself in a dark wood [where] the straight way was lost.
>
> Oh! how hard a thing it is to tell what a wild and rough and stubborn wood this was, which in my thought renews the fear!
>
> So bitter is it, that scarcely more is death, but to treat of the good that I there found, I will relate the other things that I discerned."

Fortunately the "good" and the "other things" here call for only brief treatment. First let us consider in mere outline the Nebular Theory of Laplace, and it may be best to follow his own account:

> "To arrive at the cause of the primitive motions of the planetary system we have the following phenomena: the motions of the planets in the same sense and almost in the same plane; the motions of the satellites in the same sense as the planets; the motion of rotation of these different bodies and of the sun in the same sense as the movement of revolution, and in planes only slightly different; the almost circular form of the orbits of the planets and satellites.
>
> Let us see if it is possible to rise to their veritable cause.
>
> Whatever its nature, since it produced or directed the movements of the planets it must have embraced all these bodies, and in view of the great distances which separate them it must have been a fluid of immense extent. To have given to them a movement almost circular and in the same sense about the sun, this fluid must have surrounded the sun as an atmosphere. The consideration of the planetary motions leads us to think that in virtue of an excessive heat, the atmos-

phere of the sun originally extended beyond the orbits of all the planets and that it retreated by successive steps to its present limits.

In its primitive state, as we have supposed it, the sun resembled those nebulæ which the telescope reveals to us as composed of a nucleus more or less brilliant, surrounded by a nebulosity which in condensing to the surface of the nucleus transforms it into star. If by analogy we conceive all the stars as formed in this way, we may imagine their former state of nebulosity, preceded itself by other states in which the nebulous matter was more amd more diffuse, the nucleus being less and less luminous. Thus, retreating as far as possible, we arrive at a nebulosity so diffuse as not to reveal its existance."

Then describing how under condensation and an increased rotation there should be abandoned, at successive stages, rings of vapor, he goes on to say that

"If all the molecules of a ring of vapor continued to condense without separating, they would form in time a liquid or a solid ring, but the regularity which this formation demands in all the parts of the ring and during the cooling process must have rendered this phenomenon extremely rare. The solar system offers but one example of it,--the rings of Saturn. Almost always each ring of vapors must have become broken into several masses, which, actuated with velocities showing only slight differences, ave continued to revolve, at the same distance, round the sun. These masses must have assumed a spherical form with a movement of rotation in the sense of their revolution, since the interior molecules had a lower velocity than those near the outer edge of the mass. But if one had been sufficiently powerful to reunite successively by its attraction all the others round its centre, the ring of vapors would have been transformed into a spheroidal mass of vapors revolving about the sun, with a rotation in the sense of its revolution."

We need not follow the details of the process further, but Laplace goes on to say that all of the phenomena first cited

"follow from the hypothesis which we propose, and give to it a high probability;"

and states further that

"If the solar system had been formed with a perfect regularity, the orbits of the bodies which compose it would have been circles whose planes, as well as those of the different equators and rings, would coincide with the plane of the solar equator. But one would suppose that the variations beyond number, which must have existed in the temperature, and the density of the different parts of these great masses produced the eccentricities of their orbits, and the deviations in their motions from the plane of the equator."

The hypothesis was very generally accepted and has continued to hold an outstanding position among the theories that have been offered as, at least, partial substitutes. Later investigations and discoveries have reduced the simplicity of arrangement and condition that was present to Laplace's mind. Planets have been added, Mars has been found to have two satellites, and generous additions of moons have been made to other planets. The two outermost planets rotate in a retrograde sense carrying in that sense with them their attendant moons. The outermost moons of Saturn and Jupiter revolve about their parent planets in a retrograde sense, and at a quite abnormal distance. The rings of Saturn, shown to consist of discrete masses, have their inner half rotating about the planet in a time shorter than its period of revolution, and the same is true of the inner moon of Mars. Both Babinet and Moulton have pointed out difficulties in the dynamical theory that are more than grave. Modern physics questioned the possibility of a nebula, of the vast size we know them to be, existing in a state of gas glowing at a high temperature, and retaining its frontier. The labor of Roche, supplied an explanation of certain of these irregularities. Darwin showed in his remarkable memoirs on "Tidal Friction" that in the tides there is an auxiliary agency that would account for certain other departures from regularity. Ball and others suppose the primitive nebula to have been non-gaseous and to have come gradually to a high temperature through contraction and condensation into different centres. More recent physics allows the existence of nebulæ of low temperatures as a whole, yet with particles here and there of high temperatures yielding the gaseous spectrum. The aggregate result is that to-day a majority of those competent to judge, retain the main features of the Laplacian hypothesis. Thus, Darwin writing in 1899, says:

"There is good reason for believing that the Nebular Hypothesis presents a true statement in outline of the origin of the solar system."

and Sir Robert Ball, writing in 1900:

"That the earth's beginning has been substantially in accordance with the great Nebular Theory is, I believe, now very generally admitted."

But many modifications of the hypothesis, and not a few theories that reject it, have been offered.

Chamberlin, the distinguished geologist, and Moulton, to whom reference has already been made, reflecting on the difficulties standing in the way of Laplace's theory, struck by the fact that the spiral nebulæ constitute by far the most numerous class of nebulæ, considering also certain geological demands, proposed quite a new theory. A sun passing near to a second sun excites in it, through attraction, an extraordinary tidal condition. Great protuberances on each side, in the direction of the disturbing sun ensue. Parts of those protuberances revolving in train about the parent sun condense and attract to them the smaller cooled parts of the protuberances that are to hand, as well as such other matter as may be gathered in from the space through which the system is passing. The disturbed sun in its early career presents the appearance of the spiral nebula. This theory has met with a large measure of approval rather than acceptance. Connected with it are serious difficulties. Thus, Hale pertinently asks "How can these small bodies—the projected matter from the sun—remain brilliantly luminous for many years? and, why do we not discover incipient spirals giving a bright spectrum?" If it be answered that large and small are merely relative, then may we not say with Ball, conjecturally, that the spiral nebulæ,—vast as under any consideration they must be—may be of an order quite different from what we have supposed, generators not of a stellar but of a galactic system.

Quite recently there has appeared the second volume of the great work of See, on the "Evolution of Stellar Systems." The author points out numerous objections to the theory of Chamberlin and Moulton, insisting that if the theory were true we should have the following consequences:

(1) Spiral nebulæ would be abundant where the stars are

densest, as in the clusters and the Milky Way; because their close approaches would, on the average, be most frequent.

(2) Spiral nebulæ would be especially abundant in the densest masses of stars such as the globular clusters, because close approaches would there attain maximum frequency.

(3) The spiral nebulæ should nearly always occur in pairs, for the disruption of one of two passing stars would generally imply the disruption of the other.

These consequences are not actual, and since the theory of probability of collision or approach is extremely slight, quite too slight to account for the hundreds of thousands of spiral nebulæ, See holds the theory to be untenable. As a further argument against it, though he affirms it to be unnecessary to thrice slay the slain, he quotes the objection of Miss Clerke that,

"The events contemplated in it are on a small scale by comparison with the grandiose dimensions which we must ascribe to spiral nebulæ."

Of the theory proposed by See, only the merest hint can be given. It is called the Capture Theory. Nebulæ are formed by the agglomeration of fine dust expelled from the stars by the repulsion or pressure of their light and by the electric forces. This dust collects and begins to condense and develop into a cosmical system. In the nebula a vast number of meteorites are formed by the precipitation of ions, whence small globes develope, and as the mass is widely scattered, each small globe has about it a sphere of influence within which its attraction is supreme. The result is that the small globes grow by accretion, and in time very much augment their masses. This again is a process of capture and consists in augmenting the masses of the bodies forming in a nebula, and in decreasing their number correspondingly. Thus are generated planets and moons. The acceleration of the earth's rotation is due to the fall of cosmical dust, and the resistance of the nebular medium tends to make the orbits approach a circular form.

Such, in merest outline is the main part of See's theory, and Laplace is thrust unceremoniously out of court with Chamberlin and Moulton.

Many variants of the earlier theories or hypotheses might well be touched upon, but time will not permit. I mention only in this connection that in a work, just from the press, *Essai de Cosmogonie Tourbillonaire*, M. Belot would seem to work out a dualistic theory based on a combination of the gravitational principles of Newton and the vortices of Descartes.

In the various hypotheses that have been considered, there must, one will admit, be some measure of the actual. May it not be that they seek to be too exclusive? May it not also be that in developing a criticism of a theory we may strain too far a so-called physical law, which may be a good working principle for such ranges as offer themselves in this small world that we inhabit. For example, in the temperatures and pressures that must exist in such a body as the sun, may it not be that our ordinary chemistry and physics are alien or inadequate? Thus, geometry on a small part of the surface of a large sphere is, within the limits of measurement, the geometry of the plane; but when we move out into the ampler regions of the spherical surface we need a new geometry. Indeed, the history of science is eloquent of warning against a dogmatism founded on a limited experience. Not many years ago it was generally assumed that the bright-line gaseous spectrum could come only from a molecule agitated under a high temperature, and the difficulty of conceiving a vast tenuous nebula continuing in a state of high temperature was very great. Now we know that under an electric strain, which does not imply a high temperature, the electrons in the component atoms excite in the ether the vibrations that characterise the element which is their source. Recent years have seen striking developments in physical theories,—developments that menace the classical mechanics, with its theory of energy that was and still is equal to the task of explaining all ordinary phenomena. What readjustment of theories may be necessary no one can as yet say, but it may be that in it a *critique* for our many and conflicting cosmic theories may be found.

However, this may be, enough has been said to show that in the "sounding labor-house vast" worlds are in the making along the lines of an all-embracing evolution, the main features of which we grasp, the final details of which we can never know. With Sir Edwin Arnold, schooled in the eastern philosophy to an appreciation of the vast rôle of mystery, we may ask and say:

> "Shall any gazer see with mortal eyes?
> Or any searcher know by mortal mind?
> Veil after veil will rise — but there must be
> Veil upon veil behind."