

ADDRESS OF THE PRESIDENT.

WILBUR A. COGSHALL

The question of Evolution has long occupied the attention of scientists. Especially has this been true in biological lines, and we are apt to think of the probable (or certain) changes that have taken place, either in plants or animals, in connection with the word evolution. As soon as biological investigation had proceeded to a point where significant differences and likenesses were well established among certain forms, the laws underlying the changes were sought, and are being sought. We have now a more or less satisfactory theory built up based on certain fundamentals, though it contains in part some elements of the speculative and the probable. One of these truths that seems established is that some organisms have existed in the very remote past, in a quite different form from what they now have, and that it is very probable, if not certain, that they will change their forms, habits, etc., still more as time goes on.

In a little broader way we may say that evolutionary changes are just as certain in the earth as a whole, or in the entire system of planetary bodies, or for that matter, in the whole visible universe. This conclusion is based on several physical laws which man has discovered and believes to be true. If the law of conservation of energy is true, then we have no alternative but to believe that the continued radiation of heat from the sun and the earth will eventually result in these bodies coming to a lower temperature, and that the sun will at some future date become dark, cold and dense. We must also believe that its power to radiate heat and light was very different in the remote past from what it is now. In as much as the sun is not essentially different from a million other stars in the sky, it seems very probable that the whole visible universe has undergone very great changes in past time, and will undergo changes just as great in the future.

There is really no more reason to suppose that the stars and the moon have always been as we see them now, than to suppose that because an oak tree has stood for a year without sensible change it has always been that way and will continue so indefinitely. The oak goes through its life history, or certain phases of it, in so short a time that we can see its whole history in less than a life time, but the changes in the tree while faster, are no more certain than those in the sun or earth.

There have been many attempts to formulate a theory of evolution for the earth, the solar system, and indeed the whole sidereal universe. Unfortunately, most of these were based on comparatively little scientific data and any actual proofs of reliability or truth were lacking. Most of them might better be called speculations, pure and simple, and were produced largely from analogy. For example, we have known for some three hundred years that the planets circulate about the sun in nearly the same plane, the ones near the sun moving faster than those farther away. The visible universe is apparently arranged more or less in one plane or at least is very much extended in the plane of the Milky Way, the solid figure that would enclose the solar system not being greatly different, except in size, from the one which would enclose all the stars. What would be more natural than to suppose that the whole universe was built up on a large scale much as the planetary system, the sun being in revolution with many others about some distant center. These, in turn, perhaps, revolving about another center till the whole Universe is accounted for. Some such idea was advanced by Kant who had only the Law of Gravitation upon which to base his speculations. Unfortunately he knew nothing of the distances of the stars. At that time no one knew from actual observation that the stars had any real motions of their own through space.

We know little enough of these things now, but a few facts have been established with certainty in the last hundred years, indeed most of our accurate knowledge of the stars being attained in much more modern times. It was not till 1839 that we knew the distance of a single star in the whole sky, and only in the last fifty years has it been possible to measure their motions in any very precise way.

Following the above general theory it was supposed for a while that the central point about which the whole sidereal system revolved had been located in Aleyone, the brightest of the Pleiades. It is sufficient to say that there is not a particle of evidence to sustain this conclusion, or the conclusion that the stars, as a whole, revolve about any center whatever. As far as we know the stars move in all sorts of directions and with all sorts of velocities. We are lacking now as much as a thousand years ago any theory of the evolution of the system of the stars, which is based upon observed changes in the stars themselves. The theories and speculations regarding the origin and history of the planetary system are more numerous and in some cases as improbable and impossible as those regarding the universe. The best

known of these and the one which has had the most influence on philosophic thought is known as the Nebular Hypothesis of La Place. It was first announced about a hundred years ago and has been accepted as probably representing planetary evolution until recent years although based largely on assumptions. La Place was one of the greatest of astronomers and mathematicians since the time of Newton and doubtless his name alone carried conviction where a little independent investigation and reasoning would have been more profitable. It is quite evident that La Place never regarded this theory as seriously as it was regarded by others after his death.

You are all familiar with the main outlines of the theory. It assumes that the matter now composing the sun, the planets and their satellites was once diffused though a sphere perhaps as large as the present orbit of Neptune, that in some way (unknown) the mass started to revolve and therefore to flatten at the poles and extent at the equator, and that with the radiation of heat and consequent shrinkage in volume, the revolution had been hastened and soon a point had been reached where the gravitational force at the equator was balanced by the centrifugal force due to the revolution. At this point, according to the theory, a more or less broad ring was abandoned by the revolving mass. It went on shrinking, and increasing its velocity of motion till the same process was repeated. Each ring was then supposed to collect into a sphere and go through the same process in a small way, thus accounting for satellite systems of the various planets, although there was no investigation to establish the way in which this was done, or even to show that it was possible. No doubt this whole scheme was suggested by the planet Saturn which shows a ring system very much as La Place supposed existed around the sun, but which we now know differs very materially from any of his hypothetical rings.

As stated above, this theory implies that the planets should all be very nearly, if not exactly, in one plane, that they should travel in the same direction around the sun, that the satellites of each planet should all go in the same direction and in one plane, and that the periods of revolution of the satellites should be longer than the rotation periods of their primaries. These conditions seemed nearly fulfilled at the time of La Place, but since then we have had the discovery of Neptune with its satellite very much inclined to the orbit of the planet, and revolving backward at that, we have had the discovery of the satellites of Uranus also revolving retrograde and very much out of the planet's plane of revolution. We have had, moreover,

the discovery of the two satellites of Mars, one of which revolves very much faster than Mars rotates on its axis.

A theory that perfectly explains all the known facts may get a hearing and acceptance without any great amount of demonstration, but when many important facts appear at variance with a theory it becomes necessary to show how these facts may be accounted for by the theory, or to look with suspicion on the theory as a whole.

There are many other facts than those just mentioned which cause distrust. Take for example the probable density of the ring that is supposed to have formed Neptune. If all the matter now in the Solar system were expanded till it formed a sphere the size of the orbit of this planet its average density would be about $\frac{1}{216,000,000,000}$ the present density of the sun. The density at the center would probably be many times that at the equator, which would make the density of the abandoned ring much less than $\frac{1}{216,000,000,000}$ th of the present density of the sun. This would be many times as rare as the best vacuum yet obtained. To suppose that any such mass of matter, spread out in a ring whose diameter must have been at least thirty times the diameter of the earth's orbit, ever collected in one place to form Neptune is a very great tax on the imagination. As a matter of fact it can be shown that this is physically impossible. This process involves long intervals of time and would make the outer planets much older than the earth, and other nearer planets. There is no observational data to support this idea; all that there are directly contradict it. On the supposition that the sun has radiated heat in the past as it does now, and that the shrinkage of the sun is responsible for the development of its energy, it is possible to tell how many years ago the sun was large enough to fill the orbit of the earth. The earth must therefore be younger than this. All evidences in the earth itself point to an age of a least sixty million years, and on the above assumptions upon which the theory of La Place rests, the sun, sixty million years ago, was much larger than the earth's orbit. The probability is then that the assumptions are wrong. Other more technical objections, some of which are even more conclusive, I must pass over.

Another theory of Evolution based on tidal relations among sun, planets and satellites has been elaborated in more recent years, and either by itself or in connection with the foregoing has been used to explain our present system. The application of this theory to the Earth—Moon system has been elaborated by Professor George Darwin. He supposes that the earth

and moon were originally one fluid mass, that oscillations set up in the mass by the tidal effects of the sun resulted in the separation of the mass into two parts, that the two parts raised tides each in the other and that the friction of these large tidal waves resulted in the separation of the two bodies to their present distance and the lengthening of their rotation periods to their present values.

It is, no doubt, true that tidal friction does tend to lengthen the period of rotation of the earth, and, if the fundamentals of mechanics are to be trusted, this effect must result in an increased distance between the two bodies. Some observational data in support of this theory appears in the fact that the period of revolution of the moon about the earth coincides with its period of rotation, and that probably the two planets nearest the sun keep the same face to the sun. On the other hand we know that tidal friction or any other force has failed to change the length of our day by one-tenth of a second in five thousand years. There has more recently come into general favor another and a totally different theory, from Professors Chamberlain and Moulton, of the Departments of Geology and Astronomy, of Chicago University.

They suppose that the solar system took its form from a nebula, but from a spiral and not from a spherical or spheroidal nebula. Observationally this supposition is sound. There is not in the sky, as far as I know, a nebula of the sort assumed by La Place. There are thousands, perhaps hundreds of thousands of the spiral sort. Of all the nebulae that have any regular shape the spirals outnumber all others. There are a few so called planetary nebulae which in the telescope look spherical, but which in a long exposure photograph show some other form. Some of them may be hollow spheres, but none appears as La Place's nebula was supposed to be. There are a few in the form of a ring with a star at the center, but again it must be remarked that this form is not the required form.

In a spiral nebula the matter forming the arms of the spiral is usually the smaller part of the whole mass, the greater part being at or near the center. If the law of gravitation holds among them, and we have never found an exception to it, then the particles in the arms of the spiral must be in motion in elliptical orbits about the central mass, the parts nearer the center moving faster than the more remote parts. This means that the arms must with time become more closely wrapped about the central mass and that any one

particle is, in time, bound to come close to many others, and eventually to collide with many.

If any one particle were large enough to start with, it would therefore grow by collision with other particles, and the more it grew the more power of growing it would have by reason of its increasing mass. It seems likely then, that loose, widely extended nebulae of this sort must eventually come into a system of small bodies revolving about a large central mass. It can be shown that a mass revolving in this way and suffering collision with other masses must move in an orbit whose eccentricity is continually diminishing. We should therefore expect to find, if our system has been formed in this way, that the more massive planets have the least eccentric orbits and that the smaller ones have the greatest eccentricity. As a matter of fact all of the large outer planets have low eccentricity and the smaller planets a higher amount. The greatest eccentricity is found among the planetoids, or asteroids, many of which are only a few miles in diameter.

It has also been shown that a close approach of two masses in the arms of the spiral might not result in collision, but under conditions which might easily arise, the smaller might be made to revolve in an elliptical orbit about the larger, thus giving rise to a satellite or system of satellites, and these satellites might revolve in one direction as easily as another. We can therefore account for the retrograde motion of the satellite of Neptune, those of Uranus, for the fact that Jupiter has some going in one direction and others in the reverse direction, for the widely scattered zone of the Asteroids and even for the very rapid motion of the inner satellite of Mars.

These, and many other features are not speculations as to what may have happened. They have all been made the subject of rigorous mathematical calculations, and with the supposed initial conditions are all entirely possible.

As to whether these initial conditions that we have supposed, actually existed or not—whether or not our earth and the other bodies revolving about the sun ever developed from a spiral nebula, we can not be so sure. Here it is a question of what is most probable. We are practically certain that it did not come about as La Place supposed. There are too many things mathematically impossible about that. By this theory, the development into the present system was entirely possible, and certainly no more probable evolution has been proposed.

La Place did not and could not account for his nebula. On this plan we can. I have said that the spirals far outnumber any other class in the sky.

It has been shown that it is entirely possible for a spiral to be formed and that it is probable that more spirals would be formed *than any other kind*. Here we approach the speculative a little closer and I would remind you that we have no record of any permanent form of nebula ever being formed. Of course the time over which we have any accurate record of the nebulae is very short, only the last few years in fact. Very few of these objects can be recognized in the telescope, and it is only since the invention of the rapid photographic dry plate, and the perfection of the large reflecting telescopes, that their true form and number have been found. Even with our present equipment and resources if one should be recorded on a plate tonight it might be impossible to say that it was there a year ago, or that it was not, unless it should be exceptionally bright.

With this class of objects then we will not expect much observational confirmation. From mathematical investigation we know that it is possible for a spiral nebula to be formed from the close approach of two stars. We know of about two hundred million stars in the sky and there are probably many more that we can get no direct evidence of. We know that they are all in motion with velocities ranging up to 300 or even 400 miles per second. Under these conditions we will at times have collisions. These will be relatively rare because the average distance between stars is large, thickly as they seem to be sown in the heavens. A close approach without actual contact will be much more frequent, and it is from such an encounter that a spiral nebula might easily arise.

The moon with only $\frac{1}{80}$ the mass of the earth and at a mean distance of over a quarter of a million miles has enough attraction for the earth to cause a distortion of figure, the liquid surface showing the effect of course more easily than the solid parts. Under the action of the moon there are two tides raised in the earth, one of which tends to stay directly below the moon and the other at the opposite side. That is to say, the moon causes the earth to assume an ellipsoidal form, the long axis of which would point toward the moon if it were not for the rapid rotation of the earth. What would this effect be if the moon were as massive as the earth, or perhaps twenty times as massive? If, in addition to this increased mass, we should decrease the distance between the bodies to a few thousand miles, the tides would be many times as great as they are now.

When we remember that the stars for the most part are gaseous, in many cases with an average density less than that of air at sea level, and at the

same time have very large diameters, it will be evident that the near approach of another massive body would be sufficient to cause great disturbance. The attraction of the foreign body would cause the star to elongate, the gravitational attraction at the ends of the longer axis would be decreased and the highly compressed gases of the interior would cause great eruptions toward the disturbing body and away from it. Even with the slight disturbances to which our sun is subjected we have these outbursts of material from the interior, by which material is thrown out at times, to distances of a hundred thousand miles.

If another star were to come within a few hundred thousand miles of our sun this effect would be produced on a scale many times greater. While the star was a considerable distance away these ejections of matter would be less violent, increasing in violence as the distance decreased, and, what is just as much to the point, they would be in a slightly different direction as time went on. The first masses ejected would be drawn out of a straight line and would eventually fall back toward the sun, some of them striking the surface and some of the rest so far drawn to one side as to miss the surface as they came back, in which case they would continue to revolve in elliptical orbits about the sun. Those masses, thrown off a little later, would travel farther and in slightly different directions, and would be diverted still more and move in longer orbits. After a maximum disturbance was reached the same process would go on with decreasing violence as the disturbing body retreated into space. It has been shown that the masses thrown off which did not go back to form part of the sun again, might under these conditions form themselves into two spiral arms, the whole, of course, being in one plane, as the motion of the two stars would be in a plane. That material which did fall back into the sun would give to the part where it fell a certain velocity of rotation, and we find in the sun a higher rate of rotation for the equator than for any other part. The direction of motion of the matter composing the arms of the spiral is not along the arms but across them, each particle moving in an ellipse around the central mass. If masses of different sizes were ejected, the large ones would tend to annex the smaller ones in the immediate neighborhood, and the process before described would result in a system of planets and satellites much as we have in the solar system.

We have this process still going on in a small way. The Earth attracts to itself several million small particles every day and occasionally there is a

larger one. Many of these, perhaps most of them, are in all probability matter which left the sun when the rest did and which are now for the first time brought near enough the earth to be permanently annexed. In a region where no large masses existed, the matter would continue to revolve in a finely divided state, such as we actually find in the zone of the minor planets. This zone lies between the orbits of Mars and Jupiter. In it have been found some 800 planets large enough to make a record on a photographic plate, and there is little reason to doubt that the whole number is many times greater and the size of most of them so small that we can never see them except as they collectively make a faint band of light across the sky. In this zone we find what we should expect with small sizes—that is, *very* elliptical orbits and very high inclinations. One of these planets has an orbit of such eccentricity that while its mean distance is considerably greater than that of Mars, yet in one point in its orbit it comes much closer to the earth than any body, except the moon, and two others have perihelion distances less than that of Mars.

Thus it is entirely possible that our planetary system resulted from a spiral nebula, and it is entirely possible that spirals may result from close approaches of two stars and we may even say that it is all probable, at least more probable than any other plan yet proposed.

There are still some difficulties. We must say that if our system resulted from a spiral, this spiral was not at all on the scale observed among the spirals in the sky. Such a nebula, having a radius equal to that of Neptune's orbit, were it no farther away than the nearest star, would be a very insignificant object and might fail of detection entirely. At the probable distance of most of these objects it would certainly be invisible. We can see how a star might be torn apart so as to scatter material over a space the size of Neptune's orbit, but the case is different when we consider some of the large spirals in the sky. The largest is known as the Great Nebula of Andromeda. It covers an arc of over a degree in the sky. Assuming a parallax of $0''.1$, which is probably larger than the real value, this nebula from end to end must extend over a space more than 1,800 times the size of Neptune's orbit, or 54,000 times the size of the Earth's orbit.

We have never determined accurately the distance of a single nebula and so do not know the real size of any one of them, compared to the solar system, but there is no reason to suppose they are nearer than many of the faint stars. If this is true, their volumes are vast beyond comprehension and their density an inconceivably small fraction of the density of our best vacuum. It has

been computed that if the Andromeda nebula had a density $\frac{1}{20,000,000}$ that of the sun it would have mass enough to attract the earth as strongly as the sun does. It attracts the earth not at all. Nor does it attract any other body as far as we know, many of them being much closer to it than we are.

We do not know the chemical composition of the nebulae, except that it seems to be different from every thing else in the sky. Not one has ever been seen to change its shape, size or brightness. We have always assumed that stars result from the contraction of nebulae and this is based on the idea that the nebulae radiate heat. It is not at all certain that these rare gases shine because of their heat. A mass of gas of such extreme rarity would have a comparatively small amount of heat and it would seem that this ought to be radiated into space very rapidly, and could not be maintained without rapid contraction. It is quite possible that nebular matter instead of being the raw material of stars and planets is matter in some final form after having gone through its life history. We have no observational data either way and will probably not have any for many centuries to come. There does not seem to be any very good reason for believing that matter is not being created now as much as it ever was nor for thinking that it must always endure in some of the forms we now know.

We think of space as infinite in extent. Whether or not matter, in the forms we know, is to be found in all parts of space, we do not know. That is to say we are not yet sure whether the universe is finite or infinite. There are some reasons for thinking that the system of the stars is as infinite as space itself, but it may also be possible that what we call matter is some manifestation peculiar to this part of space. The mere appearance or disappearance of matter in space would in itself be no more remarkable than the precipitation and evaporation of water would be if we knew nothing of the atmosphere, and perhaps not as remarkable as the production of water from two invisible and unknown gases would seem to people who know nothing of chemistry.

The most probable source of information it seems to me, will be the researches of the physicists and chemists on the real nature of matter. When they shall have told us what matter really is, what all of its possible forms may be and what all the sources of energy are, then we may be able to state with certainty what the life history of a star is, what relation the nebulae have to other bodies, and what in reality has been the past history of our planet and other planets.