Recent Theories About the Origin of the Solar System

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MANY THEORIES CONCERNING THE ORIGIN of the solar system, starting from a plausible, hypothetical, original situation, have been offered since Descartes, in 1644, made the first attempt to explain the observed regularities of our planetary system.

In the last decade, renewed interest has been shown in this subject, and new theories have been proposed by physicists and astronomers. Before considering these theories in detail, let us summarize briefly those features of the solar system which require explanation. As was long ago pointed out by Laplace, there are so many regularities that the system could not have been formed fortuitously but must be genetically related. This is sufficiently established by the fact that the revolutions of all the planets and asteroids about the sun are in the same direction.

Regularities of the Solar System

The solar system consists of the sun, 9 large planets, 28 satellites revolving about 6 of these planets, more than 1,500 asteroids, and the comets and meteors. Our main concern here will be with the planets.

The regularities shown by the planets may be divided into four main groups:

First, there are the orbital regularities. Apart from the common direction of orbital motion, the eccentricities of the orbits are small, and the orbital planes are practically the same. The rotation of the sun is also in the same direction, and its equator is only slightly inclined to the planetary orbital planes.

Secondly, the mean distances of the planets from the sun obey very closely the so-called Titius-Bode law. This law gives, as the expression for the mean distance of the *n*th planet from the sun, $r_n = a + b \cdot 2^n$, where $a = 0.4$ A.U. and $b = 0.3$ A.U.[1] and where the group of the asteroids is counted as one of the planets. The law

$$r_n = r_0 \varepsilon^n \qquad (1)$$

instead of the Titius-Bode law gives us, with about the same amount of accuracy, the mean distances of the planets from the sun.[2] This expression is often more convenient to use, and, when we refer to the Titius-Bode law, we will have in mind expression (1).

For the satellite systems of Jupiter, Saturn, and Uranus laws such as that given in equation (1) apply (with different ε's). Also, the orbits of these satellites show the same regularities as do the planetary orbits.

Altogether, the satellite systems are analogous to the planetary system in so many ways[3] that the conclusion seems unavoidable that the manner of their formation should essentially have been the same.

The third feature of the solar system which requires explanation is that the inner, or terrestrial, planets (Mercury, Venus, the earth, Mars) and the outer, or major, planets (Jupiter, Saturn, Uranus, Neptune[4]) are separated not only in space but also by their physical properties. The inner planets are comparatively small bodies with a high specific density, low rotational velocity, and few satellites. The outer planets, on the other hand, are large, their specific density low, their rotation fast, and their satellite systems extensive.

The fourth and last feature of the solar system which has to be explained is the distribution of the

[1] One A.U. (astronomical unit) = mean distance of the earth from the sun = $1.5 \cdot 10^{13}$ cm.

[2] For the planetary system, $\varepsilon = 1.67$. Incidentally, the accuracy of the results obtained in some astrophysical problems is far less than that with which physicists are often used to working. The Titius-Bode law is, for instance, more a rule of thumb for finding the distances of the different planets than a law which is obeyed within a few per cent. The same impossibility of obtaining very accurate results can, for example, be seen when we consider the table on page 410 to give an excellent agreement between the observed and calculated masses. But, even so, it seems that the exponential laws for the distances of the planets and satellites from the sun and primaries are more than just a coincidence (cf. *6*).

[3] Apart from the fact that there exist exponential laws for the mean distances of the satellites from their primaries, and that their orbits show regularities, the distribution of the angular momentum in the systems formed by the satellites with their primaries is very similar to that distribution in the planetary system. The sun's angular velocity is smaller than the angular velocity corresponding to Kepler's third law by a factor of 200. This factor is not quite so large in the case of the outer planets but ranges there between 3 and 6, which is still considerable. Finally, the ratio between the masses of the central body and the revolving satellites is about 1:1,000 both in the cases of the outer planets and in the case of the sun.

[4] We shall not discuss Pluto in this paper. This planet is small and dense, and its orbit has a large eccentricity. It thus differs considerably from the other outer planets.

angular momentum. The sun possesses about 99% of the mass of the total solar system, but only 2% of the total angular momentum. Failure to explain this point has caused the downfall of many theories in the past, the most notable being those of Kant and Laplace.

We may indicate here, briefly, the difficulties, first pointed out in 1884 by Fouché, inherent to the distribution of the angular momentum. The angular velocities of the planets are determined by their mean distances from the sun in accordance with Kepler's laws. The strange thing is not that the planets have such a large angular momentum but that the sun rotates so slowly.

If one attempts to account for the origin of the solar system by some kind of catastrophe, this accident may have brought about the present distribution of the angular momentum. If, however, one tries to develop a theory starting from the sun alone, perhaps surrounded by a gas cloud, it is not easy to see how the average angular momentum per unit mass should be so much lower for the solar than for the planetary matter.

Of course, the four main groups of regular features mentioned above are not the only ones exhibited by the solar system. We will not discuss here the other properties of the solar system, such as the Saturnian rings or the asteroid system. Some of these irregularities can be explained easily, while others still await an acceptable explanation.

Prior to a discussion of some of the new theories proposed during the last 10 years, it should be pointed out that all theories about the origin of the solar system can be divided into two groups, according to whether or not they assume an interaction with other celestial bodies as an integral part of the development of the solar system. In the first case, we have an open system; these theories are called *dualistic* or *catastrophic*. In the second case, the system is closed, and the theories are called *monistic* or *uniformitarian*.

For a critical survey of older theories, the reader is referred to the many excellent textbooks written on the subject (*10*). Here the discussion will be confined to the recent dualistic theories of Lyttleton and Hoyle and the recent monistic theories of Alfvén, Whipple, Berlage, von Weizsäcker, and ter Haar. A detailed criticism of these theories will be given in a forthcoming paper (*6*).

Binary Theories

Russell (*10*) pointed out that the tidal theories of Jeans and Jeffreys are unable to explain the distribution of the angular momentum, although, at first sight, the encounter of a second star with the sun seems to be able to provide the system with sufficient angular momentum. Russell himself suggested as a possible, though not very promising, way out that the sun might have been a binary star whose second component was removed by some kind of a catastrophe.

Lyttleton has followed up this idea and given two different theories along those lines. The first one (*8*) followed Russell's idea very closely and assumed that a third star collided with the sun's companion. In that way, the binary system may have been broken up and a gaseous filament provided which would thereafter condense into the planets in a way analogous to the condensation in the tidal theories. Although it seems that Luyten's criticism is not valid, there are still too many difficulties connected with this theory for it to be accepted as a final solution, *e.g.* we may mention here Lyttleton's own difficulty in accounting for the satellite systems.

The alternative solution suggested by Lyttleton (*9*) also meets with the same difficulties. In this theory he starts from a triple star. The two companions of the sun are supposed to form a very close binary. During the evolution of this binary system, they will draw closer to each other and finally the two stars will combine into one mass. This mass will, however, be rotationally unstable and will consequently break up. The result of the fission of the combined mass will be that the two fission products will leave the system, leaving behind them a gaseous filament. The further development follows the same line as in Lyttleton's original theory.

According to another Cambridge astronomer, Hoyle (*7*), who has indicated a third possibility, starting from a binary system, a supernova outburst of the sun's companion may have resulted in the breaking up of the binary system and the production of a gaseous filament. From data concerning the Chinese supernova of 1054 A.D., which was presumably the origin of the Crab nebula, Hoyle concludes that this process might not be completely impossible. His theory, however, seems to encounter even more obstacles than Lyttleton's theories.[5]

Alfvén's Theory

The Swedish physicist, Alfvén, has proposed a most interesting theory which takes into account the magnetic moment of the sun (*1*). This was previously done by the Norwegian scientist Birkeland, but he never followed up this idea by proposing a really detailed cosmogony.

Alfvén had two reasons for advancing this theory: (1) The magnetic force on charged matter due to the

[5] Spitzer (*11*) has shown, for instance, that such a hot filament will disappear by evaporation before it can cool down sufficiently to allow condensation to take place.

sun's magnetic field exceeds by far the gravitational force of the sun on the same matter in the regions of the solar system. (2) He had shown in an earlier paper that the rotating magnetic moment of the sun is able to cause currents in a neighboring ion cloud. Because of these currents the ion cloud will start to take part in the solar rotation, and the sun will be decelerated. In this way, an appreciable amount of angular moment can be transferred from the sun to such an ion cloud in a period of 10^5 years. This is short compared with the age of the solar system, which is of the order of magnitude of 3,000,000,000 ($3 \cdot 10^9$) years. The present distribution of the angular momentum is in this way easily explained.

Alfvén now proposes the following process for the formation of the outer planets: The sun is supposed to be surrounded, at a certain stage of its life, by an interstellar gas cloud. Due to the gravitational attraction of the sun, the atoms in the cloud will start falling toward the sun, and their kinetic energy will increase because of the gain of gravitational energy. Eventually, this energy will become so large that ionization through collisions will take place. Once an atom is ionized, the movement is arrested, and the ion has to move along the magnetic lines of force to an equilibrium position in the equatorial plane of the sun. In this way, Alfvén obtains a mass concentration in the equatorial plane. In this gaseous disc, condensation will take place, resulting in the formation of the planets.

This mechanism, though giving a possible solution for the formation of the outer planets, cannot account for the inner planets. The distance from the sun at which ionization occurs is too large to get any mass in the regions where the inner planets are observed. Alfvén suggests, therefore, without any detail, a different process for the formation of the terrestrial planets. He assumes that, at another stage of the sun's journey through space, it may have met an interstellar smoke cloud consisting of small solid particles. These particles will sublimate in the vicinity of the sun, the resulting atoms will become ionized, and a process similar to that described above will start, but at less distance from the sun.

A quantitative analysis of the processes discussed by Alfvén shows that they could never have played an important part in the formation of our solar system. In a gaseous system surrounding the sun which contains sufficient mass to provide for the planets, ionization will be completely negligible (*6*). However, if the sun collected the matter of the planets during its journey through space, it can be shown that it is impossible to collect sufficient material in the way described by Alfvén.

The Dust Cloud Hypothesis

Recently, Whipple (*13*) has introduced an entirely new idea into this old problem. As yet, this idea has not developed into a theory, and it seems questionable whether this is possible.

Whipple starts from a cloud in which gas and smoke particles[6] are mixed. The contraction of this cloud, which has an original radius of about 30,000 A.U., should produce both the sun and the planets.

To account for the low angular momentum of the sun, the cloud is assumed to possess negligible angular momentum. The planets are assumed to be formed in a stream in the cloud. It is assumed that in this stream there are concentrations of matter which will ultimately produce the planets. Because the planets are formed in the stream, they will possess from the beginning the necessary angular momentum. On their path through the large cloud, these proto-planets will sweep up matter with zero angular momentum and consequently spiral inward.

The solution for the present distribution of the angular momentum is included in the theory from the beginning, so that this point presents no difficulties. The small eccentricities of the orbits are produced by the accretion process, as in the tidal theories of Jeans and Jeffreys. Whipple has not as yet studied the further development of these proto-planets closely enough to be able to explain any other properties of the system, and it seems extremely doubtful whether this will be possible.

A Revival of Kant's Theory?

As is well known, the theory proposed in 1755 by Immanual Kant in his "Allgemeine Naturgeschichte und Theorie des Himmels," and given in a mathematical form by du Ligondès in 1897, was regarded as disproved because of the impossibility of understanding the present distribution of the angular momentum.

At present, however, it seems that this *communis opinio* was due to a misunderstanding of the problem, and quantitative calculations appear to show, to the contrary, that Kant's theory is probably the most promising of all existing theories.

The first author to start again from the same initial system as the one studied by Kant was the Dutch meteorologist, Berlage (*2*). He tried to combine Kant's and Laplace's theories by investigating the possibility of the formation of a system of rings in a gaseous disc surrounding the sun. From these rings

[6] This is a better name than dust particles for the solid particles existing in interstellar space, as was first remarked by van de Hulst (*5*) following the nomenclature of physical chemistry, where smoke is the product of a condensation process.

the planets should have been formed by condensation in these rings, in Laplace's theory.

The second attempt was made by the German nuclear physicist, von Weizsäcker (*12*). His theory, which was dedicated to Sommerfeld on the occasion of his 75th birthday, will be discussed here in some detail, since von Weizsäcker draws attention to a few new features of the problem. Although his attempt seems also doomed to fail, his manner of attacking the problem can help us to explain many of the features of the planetary system.

First of all, von Weizsäcker shows that a gaseous envelope around the sun which possesses an angular momentum will assume a disc shape because of its rotation. The disc, however, is not stable. It can be shown that the velocities in the disc will follow Kepler's third law rather closely, *i.e.* the angular velocities decrease as the square root of the distance from the sun. Due to the differences of velocities, viscous forces will be present, striving to set up a rotation of a rigid body. The outer parts of the disc will thus be accelerated and move outward on account of the increased velocity, and the inner parts will be decelerated and move toward the sun in the center. Eventually, the disc will dissolve completely.

This dissipation of the disc is thus accompanied by three phenomena. First of all, the viscous stresses spend energy; this energy is provided by the matter falling onto the sun and gaining gravitational energy. Secondly, there is a transfer of angular momentum from the inner to the outer parts of the system. Thirdly, the matter of the system is dissipated, part of it falling on the sun, and the other part evaporating into space. Von Weizsäcker uses this dissipation to explain the present distribution of the angular momentum. He assumes that the matter falling on the sun possesses zero angular momentum, and that the matter flying away into space has a low atomic weight and possesses the bulk of the angular momentum. In this way, he obtains a slowly rotating sun and is at the same time able to explain that the planets contain more heavy elements than the sun.

There are two objections to this solution. The first is that it seems improbable that there should occur such a separation according to atomic weight and angular momentum. Secondly, it turns out that the total deceleration of the sun due to this accretion of matter with zero angular momentum is too small to account for the slow rotation of the sun, by a factor of the order of magnitude of at least 100,000.

The next step in von Weizsäcker's theory is the consideration of a pattern of vortices which might have existed in the disc. He shows that if we may assume that the orbits of the mass elements in the disc are unperturbed Keplerian ellipses, a regular system of vortices, like that shown in Fig. 1, can be built up. If the rotation of the disc is direct (counterclockwise), the movement in the vortices will be clockwise.

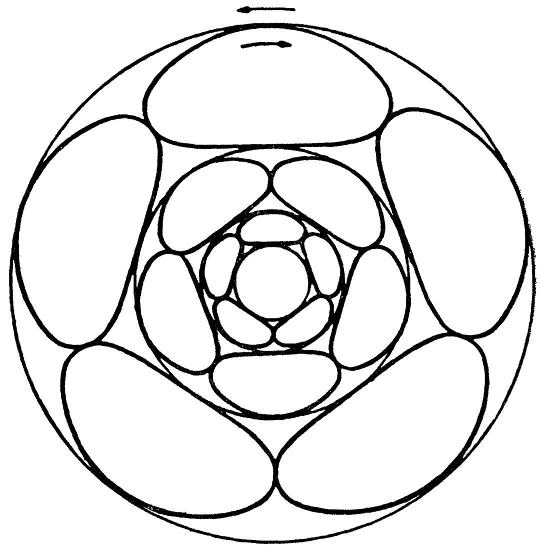

FIG. 1. The outer arrow indicates the direction of rotation of the whole disc, while the inner arrow indicates the direction of rotation in the vortices. The sun is in the center of the whole system.

Von Weizsäcker considers this system for two reasons. First, gravitational forces are by far the most important forces in the disc, so that the orbits in the disc would be Keplerian if there were no collisions. Secondly, the energy dissipation will be less in a regular system such as that shown in Fig. 1. The dissipation will take place along the circles where the rings of vortices meet. The viscous stresses along those circles, separating the main vortices, will give rise to secondary eddies. As can be shown, conditions for condensation will be more favorable in these "roller bearings," which means that we may expect the planets at distances from the sun, corresponding to the radii of these circles. In a system like that pictured in Fig. 1, the ratio of the radii of two consecutive circles is constant, thus presenting us with the exponential Titius-Bode law (*10*).

However, von Weizsäcker's reasoning cannot be accepted as final, since the mean free path in the disc is only a few inches because of the density in the disc necessary to provide sufficient matter for the planets. The unperturbed Keplerian orbits necessary to derive the regular system of vortices of Fig. 1 seem to be out of the question. Instead, one has to apply hydrodynamics. Although there are indications (*6*) that, indeed, a regular system of vortices might be a solution of the hydrodynamical equations, the above explanation of the Titius-Bode law and similar laws for the satellite systems has as yet to be accepted with reservation. It is to be hoped that a study of the quadratic hydrodynamical equations may give a final answer as to whether a regular system of vortices has once existed in the gaseous disc.

During the formations of the planets they would be surrounded by an extended atmosphere. It is reasonable to assume that the formation of the satellite systems in these atmospheres would be analogous to the formation of the planets in the original gaseous disc.

Von Weizsäcker finally gives a qualitative picture of the condensation process, showing that the period necessary to build up bodies of the size of the planets is of the same order as the estimated lifetime of the disc.

Latest Developments

In view of the fact that none of the existing theories seemed to give a satisfactory solution, ter Haar (*6*) tried to investigate in detail the properties of a gaseous, rotating solar envelope. A second reason for adding a new theory to the many which already exist was that no one had up to that moment given a *quantitative* analysis of the condensation process.

A short survey of this investigation will be given here, and it will be shown that by means of Kant's theory the differences between the inner and the outer planets may be explained.

As remarked above in the discussion of von Weizsäcker's theory, the explanation of the Titius-Bode law is still an open question. That point will not be discussed further here.

The first step in a quantitative analysis of Kant's theory ought to be a discussion of the physical and hydrodynamical aspects of the solar gaseous envelope, which will contain originally about one-half of the solar mass, and the density of which will be about 10^{-9}g cm^{-3}.

This analysis shows that the envelope will have a disc shape, *i.e.* the density decreases outward and in directions perpendicular to the equatorial plane of the sun. It also shows that ionization is negligible, and that the temperature in the disc will decrease as the inverse square root of the distance from the sun. At a distance corresponding to Mercury's mean distance from the sun the temperature will be about 650° K, decreasing to about 75° K in the vicinity of Neptune. For the mean distance of the earth from the sun, we have about 400° K.[7]

The hydrodynamical analysis enables us to calculate the rate of energy dissipation and, hence, the lifetime of the disc. Part of the matter in the disc falls on the sun, thus gaining gravitational energy; this process provides the energy lost in the dissipation process. The lifetime of the disc turns out to lie between 10^7 and 10^8 years. As we remarked before, the energy dissipation is a consequence of the viscous stresses in the disc, due to a velocity gradient corresponding to Kepler's third law. These viscous forces entail also a transfer of angular momentum. The inner parts of the disc will be slowed down. This process is analogous to the drag of a viscous fluid on a rotating disc, used to determine the viscosity coefficient.

It is possible to make a rough estimate of the transfer of angular momentum in the disc per unit time. Since it is also possible to estimate the lifetime of the disc, we are able to estimate in first approximation the total deceleration of the sun during the formation of the planetary system. Although the results are still far from final, it seems that the low rotational velocity of the sun cannot possibly be explained in that way.

Following analysis of the physical and hydrodynamical properties of the gaseous disc, the condensation process has to be considered quantitatively.[8] The condensation process can be divided into three phases: (1) the formation of nuclei for further condensation, (2) the growth of these nuclei, and (3) gravitational capture. The growth during the last stage is much faster than that during the first two stages.

Stages 1 and 2 are analogous to the formation of drops in a supersaturated vapor. From the theory of condensation it follows that the temperature determines which compounds are supersaturated at a given density. Whether or not a certain compound is supersaturated at a given temperature and density depends on its heat of sublimation. If the heat of sublimation is larger than a critical value, the compound will be supersaturated, otherwise not. The critical heat of sublimation is mainly determined by the temperature and depends only slightly on the density.

In the gaseous disc, the temperature decreases with increasing distance from the center. Consequently, in the regions nearer to the sun fewer compounds will take part in the initial condensation phases than in the outer regions of the solar system. It now turns out that, in the regions of the solar system where the terrestrial planets are found, only inorganic compounds will condense. In the regions

[7] The fact that the observed surface temperatures of the planets are lower by a factor 1.4 is due to the planetary rotation. The sun heats up only the part of the planet facing the sun. This factor was overlooked by von Weizsäcker.

[8] We may remark here that in the planetesimal theory of Chamberlin and Moulton (*4*) similar considerations were given, though those authors did not discuss the processes very extensively and quantitatively.

of the outer planets, however, both organic and inorganic compounds can condense. It is very remarkable that the change-over from inorganic to organic compounds lies just in the region between the inner and outer planets.

This has two consequences. First of all, there will be fewer condensation nuclei in the inner parts of the system than in the outer parts. Secondly, the specific density of the condensation nuclei in the inner regions will be higher than that of the nuclei in the outer regions. From this alone, we could already expect heavier, small inner planets and light, large outer planets.

This precipitation of the supersaturated compounds will continue until the bodies have become so large that gravitational effects will become important. The gas molecules are then captured in the gravitational fields of the condensation products, and the protoplanets will grow very fast until the gas is exhausted.

The bodies for which gravitational capture begins to play a role are of about the same size as Venus. From this, we see that this last stage has not been important in the building-up process of the inner planets. For the outer planets, however, gravitational capture has been important, thus increasing their mass and decreasing their specific density because of the capture of the light compounds which were not supersaturated even at temperatures of about 100° K.

The reason why the outer planets have grown beyond the second stage, and the inner planets not, is that the lifetime of the disc is of the same order of magnitude as the time necessary to reach the stage of gravitational capture. The inner planets grow more slowly than the outer planets during the first two stages because fewer compounds play a part in these stages. Therefore, the outer planets may well have reached the third stage before the dissipation of the disc became important, but when the inner planets had attained that size, the dissipation of the disc prevented an appreciable further growth.

It is possible to explain even the small differences in density of the various planets. Brown (*3*) has shown that, if one assumes that all the inner planets are built up from the same material, their densities will vary because of a variation of pressure in their interior, due to their varying masses. As for the outer planets, we have to assume that they are built up of heavier material plus some lighter gases captured during the last stage of their formation. In that way the differences in density can all be understood.

We will assume now that in the building up of the outer planets about 20 times as much of the matter in the disc has taken part as in the formation of the inner planets, corresponding to the fact that for the outer planets gravitational capture has been important. We can then estimate the masses of the planets if they should have been formed in the disc at their present distances from the sun.

In Table 1 we have inserted the values of the planetary masses, calculated under this assumption. The masses are expressed in the earth's mass as unit.

TABLE 1

Planet	Observed mass	Calculated mass
Mercury	0.05	0.1
Venus	0.8	0.5
Earth	1	1
Mars	0.1	2
Jupiter	318	130
Saturn	95	90
Uranus	15	20
Neptune	17	3
Pluto	0.9	0.8

The agreement between the calculated and the observed masses seems to be quite good.[9]

In order to get sufficient mass to build up bodies of the size of the present planets, it appears that the original solar envelope must have contained between one- and five-tenths of the solar mass, because only part of the matter can take part in the condensation process.

During their formation, the outer planets would be surrounded by extended atmospheres. The evolution of these atmospheres will probably be analogous to the evolution of the solar envelope. In this way we have a mechanism for the formation of the satellite systems. Since these atmospheres will be large for the outer planets, and practically absent for the inner planets, we can readily understand why the outer planets are surrounded by extensive satellite systems while the inner planets possess only a few satellites.

For a discussion of the extent to which the various properties of the satellite systems can be explained the reader is referred to ter Haar's paper (*6*). The analysis of these planetary atmospheres gives us also an explanation of the fact that the outer planets rotate faster than the inner ones.

In conclusion, it seems that Kant's theory is stronger than was suspected for a long time. This is rather satisfying, since Kant's theory starts from probably the simplest possible hypothesis—a sun, surrounded by a gaseous envelope.

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[9] The only serious discrepancy is Mars' mass. It may well be possible that the small mass of Mars is due to the same, as yet unknown, process which prevented the formation of a planet between Mars and Jupiter.

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The Neurological and Behavioristic Psychological Basis of the Ordering of Society by Means of Ideas

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WHAT, SPECIFICALLY, DOES IT MEAN to assert that human behavior and its attendant social institutions are significantly determined as to their form by ideas? For one thing, it means that human beings in society are reacting not merely to particular natural events occurring just once at a given time and place, but also to symbols, to socially conditioned symbols, which keep their meanings constant during the period of decades or centuries, as the case may be, in which a given normative social theory captures their faith and thereby serves as a norm for their social behavior and cultural institutions. But to say that human beings in society are reacting to natural events is to say that their behavior is determined by what is called a particular. And to say that human beings are reacting to symbols which keep their meanings constant through many events is to say that they are reacting to particulars which are the embodiments of universals.

This permits the basic problem of the present inquiry as a whole to be put more specifically. This problem has to do with the relation between ideological and biological factors in social institutions. It has been noted that social institutions embody normative social theories and that these normative social theories are a significant cultural factor in the ordering of social phenomena. But we have just noted, also, that normative social theories, unlike specific events in nature, exemplify universals rather than mere particulars. Thus, our problem of determining the relation between cultural factors and biological factors in social science becomes, in part at least, that of determining the relation between the processes of biological systems and the responses of people to particulars which embody universals.

But there is a second, more specific, portion of our over-all problem. When a given people are captured in the realm of their normative beliefs by a specific normative social theory, this theory serves in their behavior as an end. In other words, it defines a purpose. This means that if we are to clarify the relation between cultural factors and biological factors in social phenomena, we must determine the relation of normatively defined purposes to biological systems.

Previous attempts to solve this problem have produced two conflicting conclusions, which, nevertheless, rest upon a common assumption.

One conclusion was that, since human behavior exhibits responses controlled by purposes defined in terms of remembered norms which are universals rather than merely responses determined by physical events which are particulars, human behavior must therefore have its basis in extra-empirically verifiable extra-biological factors. The assumption here is that in the realm of the biological there are only mechanical causes and no purposes, only particular events and no remembered events with their persistent meanings and hence no universals. This has been the answer of the Cartesian and Lockean dualists on the one hand and of the idealistic philosophers and the German social scientists, with their distinction between the

Address of the vice-president and chairman of the Section on History and Philosophy of Science (L), AAAS, delivered at the joint Symposium (with Section K) on the Relation Between Biological and Cultural Factors in Social Problems, December 28, 1947, in Chicago, Illinois. This address is the middle section of a much longer article entitled "Ideological Man in His Relation to Scientifically Known Natural Man," in the symposium volume, *Ideological differences and world order*, which is to be published in 1948 for the Viking Fund by the Yale University Press.