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CONTENTS

Ein Prediger muss nicht allein *weiden*, also dass er die Schafe unterweise, wie sie rechte Christen sollen sein, sondern auch daneben den Woelfen *wehren*, dass sie die Schafe nicht angreifen und mit falscher Lehre verfuehren und Irrtum einfuehren.
Luther

Es ist kein Ding, das die Leute mehr bei der Kirche behaelt denn die gute Predigt. — *Apologie, Art. 24*

If the trumpet give an uncertain sound, who shall prepare himself to the battle? — *1 Cor. 14:8*

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scientist. The Bible theologian attaches no value to them. Bishop Manning, indeed, declared that "the evolutionary theory has been accepted by all schools of theologians for the last fifty years." (See *The Christian Century,* Jan. 26, 1938.) But that statement lacks scientific precision. The Bible theologians — the true theologians — do not dream of accepting this hypothesis. They refuse to let the evolutionary or the Copernican or any other hypothesis correct Scripture. As Dr. Pieper says: "It is unworthy of a Christian to force Holy Scripture, which he knows to be God's Word, into agreement with human opinions (hypotheses), with the so-called Copernican cosmic system and similar hypotheses, or to accept such forced interpretations by others." (*Op. cit.,* I, p. 577.) And Dr. Hermann Sasse describes the Christian position thus: "The Lutheran Church, today as formerly, has greater respect for the Word of God than for the hypotheses of modern science." (See *Allg. Ev.-Luth. Kztg.,* 1938, p. 82.)

However, at present we are not concerned with the reaction of theologians towards the demand to accept these hypotheses as truths. We are asking just now how much value the scientist attaches to them. The answer is: None, as far as their value as proofs is concerned. As the *Watchman-Examiner* (June 19, 1941) puts it: "You are not in the absolute realm of science when you are hypothetical. You must go outside its door when you take up a hypothesis, and you can come back in only when you have established your facts."

Facts! From the first chapter on the moderns have been telling us that "the facts" disprove Verbal Inspiration. We ask them to produce these facts — and here they are offering us hypotheses! That is counterfeiting, theological and scientific counterfeiting.

(To be continued) TH. ENGELDER

Freedom and the Modern Physical World Picture*

A discussion of the problem of free will as affected by the new physics cannot claim finality in any sense. The modern world picture is not complete, for one thing, and we are free from agreement on the epistemological background of the doctrine of freedom. Yet the problem of the will remains the most fascinating in philosophy, and the possibilities which modern physics offers towards the solution are arresting enough to deserve more than passing notice. Any serious study of the subject unfortunately

* A paper read before the Philosophical Section of the Missouri Academy of Science. Rolla, Mo., April 22, 1938.

involves factors of a subjective nature, which make their results arrived at of little absolute worth. Is freedom equivalent to purpose in nature? Is it the psychological phenomenon, as when we speak of the freedom of making a choice? Is it a combination of the two? One might also at the outset be caught in the fallacy of assumption, as when we accept a dualism, at least by implication, which really answers in advance our question whether the new physics supports the idea of freedom. Then there is the matter of competency. I am not a physicist. Mathematical studies were more or less of a blight on my college years, and for the new physics one requires novel types of algebra, which take one a good many parasangs beyond calculus. There is a crumb of comfort in knowing that even one who never progressed beyond college mathematics is not so much worse off relatively than the majority of mathematicians who turn the pages of the current mathematical periodicals or attend scientific meetings. Dr. E. T. Bell, who teaches in California Institute of Technology, says that out of fifty mathematical papers presented in brief at such a meeting, "It is a rare mathematician indeed who really understands what more than half a dozen are about. The very language in which most of the other forty-four are presented goes clean over the head of the man who follows the six reports nearest his own specialty." Fortunately the basic factors of the new physics are easily ascertained and can be set forth in non-technical, at least non-mathematical, language.

It is my conviction that no discussion of the problem of freedom can be fruitful today without a knowledge of the modern physical world picture. And I believe that the new physics presents data which confirm what introspection has long told us, that the will is free, that our actions are free in the sense that they are not necessitated, determined, made certain and predictable by antecedent factors in the total situation. I am following three lines of demonstration to set forth this interpretation of the new physics, formulated thus:

I. The elimination of the mechanistic world view implies by necessity the acceptance of indeterminism, and the only indeterminism which science holds forth is not accidental chance but free will. The strength of this argument rests on the principle of contradiction.

II. The uncertainty principle developed out of quantum mechanics throws every burden of proof on the deterministic position.

III. The progressive integrations which come to view in the physical world picture and which carry through the biological field and into the sphere of human action make a harmonious world view dependent on the idea of freedom.

I

The old physics held that matter consists of single particles separated from one another by empty spaces. It was materialistic, inasmuch as the mass points had ascribed to them, once and for all, a fixed property (inertia) and were thus made "rigid lumps of reality," which afterwards could hardly be got rid of again. This world picture is strictly deterministic, resting upon the assumption of inevitable and unambiguous causality of all physical events, and thus finally, as it appears, of all events in nature. Any other view thirty years ago was received with a pitying smile and regarded as suffering from incurable philosophical softening of thought. The world picture of present-day physics is distinctly a dynamistic one. Materialism in the narrower sense, that is, the belief in eternal indestructible matter or in atoms as "rigid lumps of reality," is abandoned. Science began to see that the assumption of a mechanical universe in which objects pushed one another about like players in a football scrimmage was as much an anthropomorphic error as the earlier animistic universe of our ancestors, in which events took place according to the caprices and whims of gods and goddesses. The ingredients of this inferential external universe, which still survived in 1900, were space, time, material bodies, forces acting on these, and a substantial ether, which filled all space and transmitted forces. Twentieth-century science, penetrating to the farthest depths of the universe, has swept these away one and all — not from choice but from necessity. Now that science has failed to find any direct action of the ether on our senses, it has dropped the ether out of its stock of concepts and finds that in so doing it can reduce the phenomena in question to complete order and consistency. The classical mechanistic idea proves to be a prejudice, a crude mode of thought based upon notions derived from microscopic processes and incapable, in the nature of things, of dealing correctly with the submicroscopic relations in the interior of the atom, just as little as the statistical results of an insurance company can give us any data concerning individual fires, suicides, accidents, etc. In the subatomic region all concepts familiar to us in the macroscopic are useless; and new ones have to be created. Let me briefly sketch the route by which we have traveled.

The original expression of the purely mechanical world picture — of a vast system of mass points endowed only with inertia — is found in Laplace's fiction of a World Spirit, who knew at a given moment the position of every mass point in the universe, together with its momentary velocity, and was further in possession of an enormous system of differential equations, according to which the velocities were connected with the accelerations. This spirit would, so Laplace concluded, be in a position to calculate all events in the past, present and future, with absolute accuracy. J. G. Fichte, *Die Bestimmung des Menschen,* illustrated the idea of an absolutely conditioned universe as follows: At every moment of her existence nature is a consistent whole; at every moment every individual part must be as it is, because all the rest are as they are. You could not move one grain of sand without bringing some change into every part of the immeasurable whole. Every moment of duration is conditioned by all past moments and will determine all future moments. You cannot conceive of any differences in the present location of a grain of sand without being compelled to alter the entire past indefinitely and also the entire future. Make the test with this little grain of sand that you see on the strand. Imagine that it lies a few feet farther inland. Then the storm that drove it in from the ocean must have been stronger than it really was. Then the condition of the weather, which determined the intensity of the storm, must have been different from what it was; and so the preceding condition by which it was determined; and so indefinitely and infinitely backward you must assume an entirely different temperature of the air from that which really existed, also an entirely different condition of the bodies which affect the temperature and of those bodies which are affected by it. This difference of climate undoubtedly has immediate effect on the fertility or infertility of the various countries and through this also upon the existence of human beings. How can you know, — simply to deal with possibilities, — how can you know whether the temperature of the universe which was required in the end to drive this grain of sand farther inland, might not have caused one of your forefathers to perish of hunger or cold or heat before he had begotten the son of whom you are a descendant? In other words, you would not exist, and all that you might do in the present or future would never exist because — a grain of sand is lying on another spot." During the nineteenth century physics held to this mechanical view. It was believed that all action is predetermined by the foregoing physico-chemical situation. Each of us is merely a stage in the working out of the world formula.

Every expansion of science was made to conform to the prevalent view. There were supposed subtile forms of matter classed as the "imponderables" — heat and light, magnetism, the vital fluid, which acted for life, and the phlogiston, which acted for combustion. When Dr. Thomas Young worked out the modern idea of the ether, 1804, the *Edinburgh Review* ridiculed it as a "metaphysical absurdity." Even the great Russian chemist Mendeleeff still firmly believed that the ether is an extremely thin gas.

As everybody knows today, the break came when the entire aspect of matter was changed by the discovery of radium in 1895. Here was an element which radiated heat at a rate probably of 3,500,000 electrons per atom, each revolving on an average of about 90,000 to 100,000 miles a second. Here was an element that drew its supply of energy from unknown sources and obeyed undiscovered laws. No mechanical model was available to carry the enormous subatomic energies released in the radioactive process. Since then the tendency of modern physics is to resolve the whole material universe into waves and nothing but waves. These waves are of two kinds: bottled-up waves, which we call matter, and unbottled waves, which we call radiation, or light. The final collapse of mechanism came with the calculations of Dr. Werner Heisenberg. Today matter is not a thing but an event. In this new world the idea of freedom is no longer an intruder but a corollary, which necessarily flows out of the abandonment of the mechanist viewpoint.

We shall next consider the change in the concept "natural laws." If we were to represent the ascendency of Law graphically, we should draw a sharply rising line from Kepler to Galileo to Newton. Kepler's Laws expressed with almost perfect accuracy the observed motions of the planets in geometrical terms, yet his explanation of nature was still thoroughly animistic or mythological. Only later in life he declared that science must make no assumptions except such as can be actually deduced from experience. His proof that matter cannot of itself pass from rest to motion gave the starting-point to Galileo, who elaborated the modern theory of motion, which forms the basis of physics. He formulated the laws of motion, which expressed the rate at which bodies fall in quantitative terms. Newton generalized Galileo's laws of motion and, inventing a mathematical symbolism which enabled him to handle and discuss succinctly yet accurately the results of Kepler and Galileo, proved that Galileo's law of falling bodies and Kepler's calculations of the planetary orbits were based on the same fundamental principle. In our graph this strictly deterministic principle of law would be represented by a long horizontal line or plateau spanning the two hundred years from the death of Newton to the publication of Heisenberg's principle of indeterminacy. If there were any doubts as to the universal reign of law, they were allayed by the justification of the Newtonic system through the impressive predictions of Adams and Leverrier, who showed that slight discrepancies in the motions of the outer planets could be explained without abandoning Newton's general hypotheses, if there were some planet, hitherto unknown, at a certain point whose attraction distorted the simple trajectories which had been expected. The observation was made, and the planet was found in the predicted spot. Who is not reminded of the even more sensational achievements in the microcosm which chemical research has scored in the last half century, when the vacant spaces in the atomic numbers were filled out by the discovery of elements the very existence of which would have remained forever unsuspected if it had not been for the faith of scientists in the unbroken uniformity of law. Yet it should be said that there were early suspicions that the parts of the universe have a certain amount of "loose play," that the world is not quite so orderly, so continuous, so inert, so carefully predetermined, so absolutely single, as we used to think.

Today we no longer treat the laws of nature as an actual something (not far removed from an impulse, or urge) that results in the phenomena of heat, light, and motion. According to the accepted view, the alleged laws of nature are only our description of certain similarities which we have observed in the happening of events. For one thing, the simple synthesis of "least action" has not proved capable of explaining everything in nature. At first it could be altered and extended so as to bring new phenomena under its scope, but — ominous sign! — with each extension it became more intricate and, to all appearances, more artificial, until finally it broke loose from the facts altogether; nothing could make it fit. Next the principle of conservation, though it continued to hold quite well for closed systems, was found not to hold within the limits of experimental error, and, above all, the universe no longer was a closed system. Even Ramsay's and Soddy's investigations into the nature of radium had brought about sharp modifications of the theories regarding natural law. Here, somehow, the continental divide was reached, and today the notion is no longer absurd that an electron and a proton may sometimes combine so as to annihilate each other. In the 1935 volume of the Smithsonian Institute records, Carl D. Anderson of the California Institute of Technology reports that his own experiments and those of others "have failed to show any certain evidence that the positrons are not created along with negative electrons by the incident gamma radiation. . . . When a positron meets a negative electron, both particles will suffer the fate of complete annihilation." Evidently Millikan is right when he says: "Conservation of matter in its ninteenth-century sense is invalid."

"Law" today is a term used to designate energy at work. Laws are but names we give, as the result of observation, to the repetitive constancy of temporal events. They are statements embodying statistical averages of the manner in which a substance behaves. It is true that considerations of this kind do not alter the dependence of the physical course of events upon statistical regularity to an extent which in practice amounts to absolute calculability. In our every-day world nothing has been overthrown or has collapsed; what held previously still holds today. In his method the scientist is, and must forever be, materialistic. In his laboratory work he never finds any spiritual power interfering with the atoms; he is a "mechanist" in the sensible meaning of the word. I also take note of the Neo-Scholastic position, which admits that events in nature have only an average, or statistical, uniformity; that no one can say in advance which one out of 2,000 atoms of radium will explode next and disintegrate this year; still Father McWilliams points out. . . . "That the individuals may be acting under no law that we can exactly formulate, I grant. That they can be acting under no law whatever, I deny." (*Cosmology*, p. 153.) But when all this is said, it remains true that heat, transmission of sound, etc., can really be properly grasped only when they are treated as the sum of innumerable single molecular processes, which we are not able to perceive as such but only to treat theoretically, but which nevertheless, taken together, produce what we see, hear, etc. Laws set up in this way by physics obviously only have the character of average statistical rules. When any one shakes up black and white sand in a vessel together, he will not expect to get anything except a uniformly gray mixture.

From these considerations we conclude that determinism is out of the picture. The only possible alternative is indeterminism. I hope to show in a later section that chance is inadmissible. What remains is Freedom, Purpose, Spirit. Professor Chambers of Washington University, St. Louis, said in 1927: "Modern physics is not so sure that it can get along without mind as was the older physics. The 20th century seems conclusively to have discarded the controversy between materialism and spiritualism, for we are coming to see that these are not abstract opposites but the poles of one and the same reality, even as electricity has its negative and positive poles." Strangely enough, the physicist and the chemist, whose labors once gave scientific basis to materialism, lead the van in the rehabilitation of spirit, while the biologist brings up a reluctant rear, and the psychologist, hugging his Behaviorist delusion, seems to insist on rounding out his forty years of wandering in the mechanistic desert.

II

The first stage in the emancipation of the physical world concept from the idea of fixed, inexorable laws was recorded when Maupertuis discovered that there was a quantity known as the "action" associated with the motion either of a single object or of a group of objects, that each bit of motion involved a certain calculable rate of expenditure of "action," and that, no matter what forces were in operation, objects moved in such a way as to make the total expenditure of action a minimum. There was no obvious physical reason why this should be, although Maupertuis advanced one of a metaphysical nature, arguing that the perfection of nature required the greatest possible economy in the expenditure of action. Since the time of Euler and Laplace the product of energy and time has been known as action. In the new physics neither masses nor energies exist primarily but only actions. We have only a something which occupies at once time and space, namely, "action," and the fact that this something is "quantised," that is to say, exists only in multiples of the unit quantity h. The law which sums up the whole of mechanics is the principle of least action.

The next step was achieved by a combination of various new forms of higher mathematics with the investigation of electromagnetism. According to the investigations of Lorentz, Rutherford, Bohr, and others, an electromagnetic wave is not a mechanical oscillation but a periodic change in the field. A wave, then, is any kind of periodic change of state which is propagated in space with a finite velocity, a periodic change of some quantity, no matter of what kind. If the temperature in a room were to change periodically (say up and down by ten degrees every quarter of an hour), the physicist would say that it is executing oscillations with a quarter-of-an-hour period. Exactly the same meaning is to be attached to the statement that broadcasting and light waves are electromagnetic waves.

This was followed by the discovery that the ultimate particles of matter — electrons and protons — behave very much like waves. We now know that it is quite impossible to divide nature up into particles and waves; we can no longer find any sharp-cut distinction between them. The synthesis of "least action" shows how this can be and is found to give a satisfactory explanation of the behavior of both particles and waves.

Enters a new dynasty — Planck, Einstein, De Broglie, Schroedinger, Heisenberg, Compton, names — we can say this today with complete certainty — that will be named as long as men live who pursue science and know something of the achievements of their forefathers. The decisive step was the development of an "atomic theory" of electricity. According to this doctrine, — and none is more securely anchored in all the range of human knowledge, — energy, like matter, can be transferred only in multiples of very minute but quite definite "quanta." Just as matter exists in no smaller particles than atoms, or protons and electrons, so does energy exist in no smaller amounts than the quanta. The magic formula E=hv expresses mathematically the fact that the energy quantum is proportional to the frequency. The factor *h* on the right is the famous Planck's quantum of action; it is a number of universal validity, which in metric units (centimeter, gramme, second) has the excessively small value of 6.55 thousand quadrillionths (or 0.0000, etc., 655, the 6 being in the 27th decimal place). The amount of energy which can be transferred is always a multiple of the product of this amount *h* and the frequency *v* of light and thus increases proportionately with the latter.

The light quantum hypothesis, as such, dealt a severe blow to the ideas of continuity and mutual interpenetration of all actions, which ideas lie at the bottom of classical physics. When investigating the scattering of X-ray, Compton found the curious peculiarity that the diffused, or secondary, wave-length is not identical with the incoming wave-length. The wave theory is entirely unable to explain this result. The Compton effect must be regarded as a direct proof of the corpuscular theory of light, advanced by Planck and Einstein. The new theory undertook to interpret material corpuscles themselves as wave phenomena.

An incidental reference like this does not of course do justice to the genius of De Broglie and Schroedinger, to whom we owe these new discoveries, and it also fails to express sufficiently the double character, wave=corpuscle, which according to this theory is the property of matter. In the world picture as it may be perceived in the Riemann-Minkowski-Einstein world, space, or time, far from being empty, *a-priori* forms of cognition, are actually assimilated to the physical "thing." The world becomes space, time, and matter, as a single inseparable unity. The waves in Schroedinger's system have no longer any material "carrier." The whole material notion of substance disappears in our hands. What remains of plain, real, hard, sharp, heavy, etc., matter? A certain probability depending on formal mathematical laws that energy or impulse is observable at a certain world point! This is the same as saying that from our picture everything has dropped out except purely mental concepts. Again, it may be said that it could not be otherwise, since science has deliberately excluded all else from its purview. But the essential point is not that science has done this. It is that science found itself forced to do this by the hard facts of nature. One physical concept after another has been abandoned, not from choice but from necessity, until nothing is left but an array of events in the four-dimensional continuum. But if only, as seems now probable, only quanta of action exist, units which extend over a certain small region of the whole four-dimensional world, it can now be maintained that in these small dimensions there exists — within the limits of the Heisenberg relation — possibly or probably a certain freedom, so that every calculation of a future state of the world based upon the present state has in it an element of uncertainty, which becomes greater, the greater the time interval.

Today the world no longer is made up of individual bodies marked by extension and occupying a position of space which itself extends endlessly into all directions. Space and time have been united into an inseparable union. This space-time or world-metric is inseparably bound up with matter, and finally energy and mass are looked upon as essentially identical. Albert Einstein, this incomparable genius, who is still in his fifties, from the beginning took the view, based on his explanation of the photoelectric effect, that the energy in radiation itself, in the field therefore, is to be regarded as divided into quanta, and these quanta are understood to possess a corpuscular structure even in free space. Energy and mass were ascribed to light. Indeed, there exists a very close relationship between mass and energy, so close in fact that mass and energy may be considered as two aspects of the same entity.

Some of us have had the high experience of being permitted to see this new concept of relativity enter into philosophical thought. In December, 1919, the Physics section of the American Association for the Advancement of Science met at Soldan High School in St. Louis. None of us who were attracted by the announcement that a report would be heard on Professor Einstein's discovery were prepared for the shattering effect of the details then for the first time were reported to a congress of American physicists. I still have the jottings of what impressed me then as the high points of the lecture: "Time and length have no meaning. We cannot say that we 'measure' time. Centrifugal force is a purely fictitious thing, gravity has no reality; both are the result of the transformation of your axes. Einstein proves that energy has mass. Force, ether, potential energy, are nonsense."

We have now had time to think it over. We are agreed, I think, that we have to discard space and time as objective realities. Forces and mechanism have dropped out of the picture altogether, and we have discovered that, whatever matter and radiation may be, they are very different from anything we used to imagine. The presence of a gravitating mass such as our earth does not "draw a body off from its rectilinear path," as Newton thought, by exerting forces; it twists up the framework so that the path of "least interval" itself becomes curved. There was nothing new in the idea that experience cannot be interpreted in terms of space and time. Ever since the time of Berkeley it has been customary for the majority of metaphysicians to proclaim the ideality of time, of space, or of both. But they soon made it clear that in spite of this, time would continue to wait for no man and space to separate lovers. The only practical consequence that they generally drew was that their own ethical and political views were somehow inherent in the structure of the universe. But so long as space and time did not break down in their own special sphere, that of explaining the facts of motion, physicists continued to believe in them, or, at any rate, what was much more important, to think in terms of them for practical purposes. What Einstein has done was to tie Minkowski's "space-time," or, in the language of the theory, world metrics, to matter, indissolubly. A doctrine opposed to both the classical mechanistic and the pure electromagnetic conceptions of the world.

The differences between the result of the more exact Einstein theory and the classical theory afford a number of possibilities for experimental tests of the new theory, three of which have become especially famous: the rotation of the perihelion of the inner planets, the deviation of the light from the fixed stars in passing by the sun, and the displacement of the spectral lines towards the red end under the influence of the gravitational field of the stars. Newton's calculations have been verified to an astonishing degree. The perihelion of the orbit of Mercury has for many years been known slowly to advance in the direction of the planet's revolution, the observed amount being 574 seconds of arc per century. Of this amount 532 seconds have been calculated to be due to the influence of the other planets. Thus there has remained an advance of 42 seconds to be accounted for. Within one point the deductions from Einstein's theory of relativity removed this discrepancy, which had baffled astronomers since the time of Leverrier. It has aptly been said by Mr. J. B. S. Haldane (in his *Daedalus*) that "without doubt Einstein will be believed. A prophet who can give signs in the heavens is always believed. No one ever seriously questioned Newton's theory after the return of Halley's comet. Einstein has told us that space, time, and matter are shadows of the fifth dimension." Most of the work of Einstein consists in deducing the consequences to space and time themselves of their ideality. These are mostly too small to be measurable, but some, such as the deflection of light by the sun's gravitational field, are susceptible of verification, and, as already stated, have been verified. The majority of scientific men are now being constrained by the evidence of these expriments to adopt a very extreme form of Kantian idealism. The Kantian *Ding-an-sich* is an eternal four-dimensional manifold, which we perceive as space and time; but what we regard as space and what as time is more or less fortuitous. Yet in one respect, and an essential one as concerns our present discussion, the relativity theory of fifteen years ago still agreed with the classical: it was strictly deterministic. It was still limited to a system of exactly valid differential equations.

The final break with mechanism came through the incredible degree of perfection achieved in the technique of the world of electrons.

In atomic and subatomic phenomena we seem to be faced by a state of affairs that lies quite outside the cyclic scheme. A most notable characteristic of this region is that strict causality, a cardinal assumption in science, does not seem to apply. In the motions of individual atoms and electrons there seems to be an element of free will. Determinism has broken down, and the principle of indeterminacy has taken its place.

For the understanding of Heisenberg's principle of indeterminism all concepts derived from our common mode of viewing nature fail. The mathematics employed by Heisenberg requires not only technical experience but imagination of a high order and has been developed by Born and Jordan into a method of still greater mathematical abstraction, namely, matrix mechanics. Fundamentally the principle can be stated in common terms by saying the more exactly we are able to determine the position of a particle, the less exactly we are able to determine its impulse; and the more accurately we are able to determine the energy, the less accurately we are able to determine the time. In other words, it is impossible to determine with a high degree of precision both the position and the velocity of an electron — though either its position alone or its velocity alone could theoretically be so determined. The reason for this is that, in order to be observable, the electron must be illuminated and scatter light to reach the eye; but in scattering this, it receives from the light a kick, *i. e.*, its momentum is altered by the process used in observing it. Now, we cannot determine experimentally what its momentum was or what it would have been if it had not been acted upon by the light-quantum, nor can we predict precisely the amount of the kick. What is inferred from this by Eddington is that "the description of the position and velocity of an electron beyond a limited number of places of decimals is an attempt to describe" — not something which lies beyond the reach of exact scientific determination — but "something which does not exist." The fact that "an association of exact position with exact momentum can never be discovered by us" must, it is suggested, be explained by the assumption that "there is no such thing in nature." When an electron is not interacting with a light-quantum and is therefore unobservable, it "virtually disappears from the physical world, having no interaction with it." It takes Professor Lovejoy seven pages of his

The Revolt against Dualism to explain why this does not make sense to him. I can only subscribe fervently to the proposition that it doesn't, but I am intrigued by the readiness with which the application of Heisenberg's Uncertainty Principle from cosmic to human values was made by men of distinction in the field of physical science. Schottky and Nernst were among the first expressly to cast doubt, on the basis of the new light-quantum theory, upon the ideas of causality hitherto generally accepted. Born and Eddington are convinced that the final abandonment of strict causality of all happening is really the last word. Haas in the following words: "If a precise description of atomic events in the classical sense is impossible in itself, the causal principle naturally loses its meaning for physics." Schroedinger himself appears of late inclined towards this interpretation. At any rate, he has expressly assented to the radical doubt concerning the traditional concepts of causality. And Bernhard Bavink now regards the feelings of freedom and the need for causality as "obviously only two sides of one and the same set of facts."

If many have welcomed the new outlook as a settlement of the old conflict between freedom and determinism, others are strenuously opposed to such an idea. With C. G. Darwin they contend that the question is a philosophic one outside the region of the thought of physics. They point out that, if an experiment is carried out with a thousand electrons, what was a probability for one becomes nearly a certainty in the case of the larger mass. Now, to find room for free will within the realm governed by physical science, we have to suppose that the motions of our own bodies are in some way not free to obey the inexorable commands of the older mechanics. But even if laws have only the value of statistical statements, it is evident that the millions of electrons in our bodies will behave with extreme regularity and that any uncertainty would have to wait for a time fantastically longer than the estimated age of the universe. Sir Arthur Eddington, however, believes that the difficulty is not insuperable and that any breakdown of determinism in the world will open the door slightly for indeterminism also in human psychology.

To conclude this section of our study: Heisenberg's principle does not indeed affect the problem of freedom in a direct or causal way. There is no connection between the freedom within the atom and that within the human mind. However, the last word has been spoken regarding necessity in the physical world, and the entire burden of proof now rests on the determinist position. The argument against free will based on man's inclusion in a closed system of cause and effect has now taken revenge from the mechanistic scheme from which it originated.

III

The new physical world picture brings a number of emergences, advances from lower to higher levels, parallel with an increasing complexity, which holds some relation to the problem of freedom. I am not speaking now of those emergences to which we have become accustomed in the discussion of evolution: life, consciousness, the backbone, the nourishing breast, mind, personality. I am thinking of the advance in complexity which at certain points insensibly passes into a new integration, governed by a new principle which with references to the preceding stage must be termed transcendental. I am thinking of the impossibility of defining the boundary between emulsions and true solutions. I am thinking of the fact that the law of entropy can no longer be assumed to hold in the neighborhood of absolute zero. I am thinking of the well-known fact that out of existing units on a lower plane units on a higher plane are formed, from atoms molecules, from molecules micellae, from these the chromomeres and other constituents of the cells, from these the cells themselves, from them the multicellular organism, from these again symbioses, associations, etc., and in the case of human beings, finally, families, states, and alliances, which are all (to use Driesch's expression) "more than the sum of their parts." From the atom to the world of fixed stars, from amoeba to humanity, there is an almost uninterrupted series of steps in the formation of ever higher and more comprehensive wholes. And now there is an end to the physical domain. Always as man has delved deeper and deeper into the universe's structure, he has found finer and more detailed construction. Atoms showed their electrons, but now the bottom has dropped out. Schroedinger and Heisenberg have spoken. There is an end to knowledge not because of a limit to endeavor but because of the nature of knowledge itself. Before the infinitesimal is reached, meaning ceases.

As one who has not been professionally engaged in modern physical research, I may confess that nothing so intrigues me in the study of Philosophy of Science as the magnitude of results achieved with experimentation on values so extremely refined as to leave the imagination helpless in their presence. We have long known that in the more recent speculation on the nature of the physical world the quantity defined as the product of two conjugated coordinates p and q was given the name action. We are also given to understand that the first form in which the quantum theory was stated implied that this quantity, the action, was atomic, *i. e.*, that it could be transferred only in units of finite size. But we were not prepared to hear that this radical change in our picture of the physical world was produced by calculations dealing with almost infinitely small particles. Prof. F. A. Lindemann of Oxford, addressing the British Institute of Philosophy in 1932, explained that an oscillation of the balance-wheel of a watch involves some 10^{25} atoms of action. He goes on to say that the number of drops of water in the oceans of the world is of the order 10^{25}. Yet it is in these regions of almost pure thought that quantum mechanics operates with its non-commutative algebra.

Within the atom the electron is thirty-eight times ten billionths of a millimeter. I am well aware of the fact that, of course, according to the newest physics, all such measurements can be understood only if we employ a mathematical scheme which no longer operates by the ordinary rules of arithmetic. It is impossible to see how a particle of the mass of an electron could be confined to a region of space as minute as a nucleus. This difficulty cannot be resolved on the basis of the older theories. They were developed to describe the properties of an atom in which the regions of space involved are of the order of, say, one billionth of an inch; they become meaningless when applied to phenomena confined to regions of space a thousand times smaller in extent, such as those required for a nucleus. It is a startling fact but pertinent to our investigation that, when nature is arranged in films of one millimicron, they suddenly possess other properties than those which it had in thicker layers.

Referring to the quantum theory, General J. C. Smuts in 1931 said: "Even in physics, organization is becoming more important than the somewhat nebulous entities which enter into matter. The partial truth of mechanism is always subtended by the deeper truth of organicity, or holism. The emergence of this organic view of nature from the domain of physics is a matter of first-rate importance and must have very far-reaching repercussions for our eventual world-view." We are obviously only a short distance away from the goal of a final unified summary of all physical knowledge, and the question as to whether this goal will be the expression of a necessary or an indeterminate "thusness" is obvious and inevitable.

This, of course, is eminently true as we pass upward from the crystal to the cell. There is an immense increase in complexity as we enter the domain of living matter. We can form mathematical representations of it, but our thought processes falter long before we reach the truth. Consider only that of carbohydrate molecules. Many varieties have one hundred to two hundred atoms each. Now, the smallest cell is one ten thousandth of a millimeter in diameter. It may have ten thousand protein molecules (Errera), and each molecule contains hundreds, some contain thousands, of atoms, and these are as real as cannon balls. Laid one layer deep, it requires one thousand billion to complete one square inch. In weight the smallest cell is 1.6 times one sextillionth of a milligram, and a sextillionth gives you a figure with twenty-one zeros. According to recent investigations by American biochemists, the molecular weight of an enzyme gene is 50,000. Dr. Ralph Wyckoff of the Rockefeller Institute, who has estimated the molecular weight of the virus of the mosaic disease in the tobacco plant, places it at the tremendous figure of about 17,000,000, and with this complexity go functions as little related to the mere multiplying of atoms as the simple multiplying of bits of steel makes a typewriter. Prof. Hans Spemann of the University of Freiburg has reported the discovery of certain enzymelike substances whose chief function seems to be the guidance of simple cells into the formation of physical organs. Under their mysteriously operating influence the cells shape themselves into stomach, liver, ear, eye, brain, or whatever may be needed to complete the animal structure.

Between the various levels of reality with which we deal in natural science, — I am not dealing with the philosophical levels of reality, such as sensation, ethical values, esthetics, etc., — there is something of the relation which exists between a regular polygon, inscribed in a circle, whose sides are being constantly doubled in number, so that the perimeter of the polygon will constantly approach the circumference of the circle as its limit. In the case of a regular hexagon inscribed in a circle it is evident that as the number of the sides is increased by the ratio 2 in geometrical progression, we shall have the series 6, 12, 24, 48, 96, . . . ? That is to say, the number of sides will increase indefinitely toward the limit — infinity; and simultaneously — with every step in the progression — each side of the hexagon will be diminished by one half its length, thus forming an inverse series progressing steadily to the limit — zero. To wit: 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ . . . 0. The limit of the entire development, then, will be represented by the expression ? by O, which signifies that the polygon will never attain its limit until the number of its sides becomes infinite and the length of each zero; which means again that this limit will not be attained until the polygon as such has been completely annihilated. In its place we have a figure totally different in kind therefrom, the circle. In short, the circle does not differ from the polygon in degree but in kind; it is not a polygon developed to an immense number of (finite) degrees, — *i. e.*, a polygon developed to "the nth degree," — not a "highly developed polygon"; but an altogether different kind of entity. However, it is obvious that the greater the number of its sides, the more "circular" or "circlelike" does the inscribed polygon appear, and a polygon of a thousand sides (could we construct it) would doubtless be indistinguishable to the eye from a true circle, though differing fundamentally therefrom. It is just this deception of mere appearances which we notice, for instance, in the grand spectrum of electromagnetic waves, in which the visible band of light rays is but a small fraction. It is this deceptive continuity that causes us to overlook the emergence of new processes at certain stages of diminishing wave-length. There are here subdivisions that belong to altogether distinct categories or orders of existence. And as each new category arises, there is a closer approach to freedom.

This is noticeable even in the case of the lowest one-cell organism, the amoeba. Once the behavior of amoeba, stentor, and paramaecium were described exclusively in mechanistic terms (such as "tropisms"). Today we know that their activities involve the same characteristics as the behavior of higher animals. The amoeba seeks food and endeavors to escape from its enemies, including its cannibal fellow-amoebae. From here on upward, organic life is characterized by a kind of behavior which the word spontaneity defines more accurately than the phrase mechanical necessity. At the organic level factors enter upon the scene which we speak of as interests. And now, as we pass through higher levels of life, Nature seems to be struggling to free itself from the mechanistic chains. Means and end take the place of cause and effect. Determinism is not disproved; it is simply transcended.

It has been pointed out by L. T. More of Cincinnati that the very idea of energy changes as we pass from the crystal to the cell. The phrase "vital energy" is irritating to a physicist, and rightly so. Ordinary chemical laws no longer apply. This is the borderland between physical and psychical laws. As the structures become more complicated, a new method of calculation is needed, probably a *Gestalt* mathematics. For elementary psychical structures do not unite additively (as do physical forces in parallelogram of force), but the lower *Gestalt* merges into the higher. This demand for a new *Gestalt* mathematics for the discussion of biological problems has actually been made by Friedman and by Bavink. The conception of causal activity common to the sciences which study inorganic nature cannot be transferred without further criticism to the examination of life and mind. An astronomer, we are told, given three good positions of a comet, can with reasonable accuracy predict its appearance a thousand years hence. This same astronomer, given three good positions of a robin on the lawn, cannot predict the direction of its movement a second hence.

From chance combinations the living cell is distinguished as being a true biological whole; it really forms a *Gestalt* in Kohler's sense, that is, a system in which each part contributes towards the existence of the whole. As we proceed from the cell to the thinking mind, we observe the emergence of new integrations passing through the biological field into the sphere of human action. The beginnings of all human faculties are to be found in animals, but in order to turn such a faculty into the power of a human being, a certain something must be added. This something is what is usually termed mind. It is obviously related to the low physical life of animals in the same way that the organic is related to the inorganic. One does not exclude the other but includes it and brings it into a higher and more comprehensive region. In other words, we have here a new emergent, characterized by self-consciousness (the ego) and the feeling of possessing freedom of will. As complexity increases, calculability decreases. For man there is not only the extremely complicated body structure but also the fact that his environment is not only his world, as the animal, but *the* world. Thence, by another evolution of the polygon into a circle, the field of values — the free moral agent and the lover of beauty. On yet a higher level, the spiritual, and with it the liberty of the children of God. "There is something" — wrote, not a dreamer and poet, not a mystic theologian, but a hard-headed physicist, Professor More of Cincinnati, less than ten years ago, — "There is something that is not dust at all, though as in all things else it is found therein; something that is the Order of the Cosmos and the Beauty of the World; that lives in all things living and dwells in the mind and soul of man; something not fulfilled in physics, which vivifies the dust and makes the dry bones live. You can call it entelechy, you may call it the Harmony of the World, you may call it the *élan vital,* you may call it the Breath of Life. Or you may call it, as it is called in the Story-book of Creation and in the hearts of men — you may call it the Spirit of God."

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