SCIENCE CHANGES ITS MIND

BY WALDEMAR KAEMPFFERT

VICTORIAN science was highly offensive to poets and theologians because it reduced the universe to a machine in which man had no purpose. God was an engineer who had designed the mechanism and who turned a crank and made the stars and planets move in predetermined ways. Some natural laws had been discovered that made it possible to predict exactly what would happen under known circumstances. Thus all the eclipses that will occur for the next thousand years were tabulated, with the certainty that the times given for the total obscuration of the sun were correct. The same inevitability was found to lie at the base of all engineering and chemistry. Steam engines, electric generators, incandescent lamps, hoisting machinery — they resulted from applying natural laws. If man seemed to stand apart and to exercise free will in an erratic way, it was because he, too, was a machine, but a machine so much more complicated than a steam-engine or a solar system that too little was known as yet about his atoms and their interrelations. Even so distinguished a mathematical physicist as the late Lord Kelvin, perhaps the most brilliant scientific mind of the late nineteenth century, found no satisfaction in a theory that could not be explained by a mechanical model. The machine worked so splendidly that science was sure of itself. Ultimately every little tooth on every little cog would be known and plotted. Nothing would be impossible in exact science.

That mechanical universe is now gone. Yet paradoxically enough, the poets and the mystics have not discovered it. Indeed they have reconciled themselves to it; they glorify it; they sing of steel and bridges, test tubes, and speed; and they fancy themselves *en rapport* with the scientific movement. Yet physical science has discarded the machine and has begun to look to the poet and the mystic for enlightenment. A man like Professor Alfred North Whitehead actually quotes Wordsworth and wonders whether *The Excursion* is not closer to reality than the astronomers who photograph stars and the physicists who measure forces in laboratories. Science has never been so unpretentious, so meek, so idealistic.

It must be said for the old Victorian machine-universe that an educated man could understand it even though he were not a trained physicist. A diagram could be drawn or a model built that was comprehensible to anyone who drove an automobile. But the heavens now declare the glory of God and the structure of matter in equations. The popularizer of science who tries to explain in accordance with the new knowledge why the planets circle around the sun, why stars shine, or why stoves send out heat finds himself much in the position of trying to give an Eskimo some conception of *The Star Spangled Banner* by wordy analogies. There is nothing to do with a song but to sing it. Never can the most poetically moving talk reveal it. Unfortunately, the equations in which the closed, finite universe or the atom of to-day is explained cannot be sung or played on the piano. Either we must become mathematicians or accept the seemingly mad conclusions of the theoretical physicists on faith.

ELECTRONS AND MYSTICISM

TWO DOCTRINES have governed the course of physical science in our day. One, the Theory of Relativity, has transformed our conception of time and space and of mass and energy; the other, the Principle of Uncertainty, has enthroned free will. The Theory of Relativity gave us a universe as obedient to law and order as that of Newton; the Principle of Uncertainty, an atom composed of capricious

and mysterious electrons. In place of the beautiful Victorian simplicity and self-consistency we have confusion. We have a universe that is younger than the stars of which it is composed, matter which is mere emptiness and in which substance is meaningless. Even the old trust in experimenting, testing, and measuring is gone. It turns out that the most searching experiment is but a kind of wish-fulfilling. We try to measure the forces within an atom only to find that our measuring rods are worthless. And we end, for the moment, in a questioning despair. Is the universe unknowable?

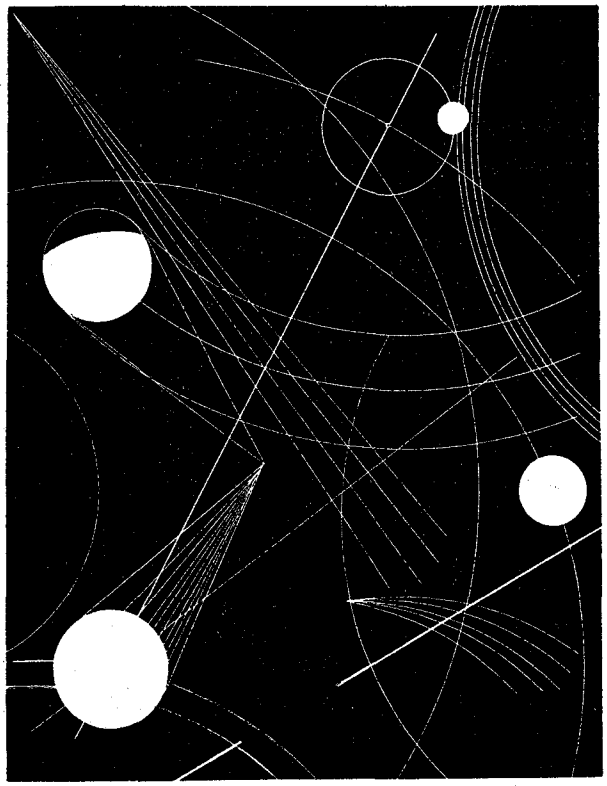
The old Victorian machine began to creak badly at the opening of the century. It was found that the luminous stream in an X-ray tube could be drawn aside by a magnet — a strange behavior of what was later found to be light. The stream proved to be composed of particles of electricity, called electrons — particles much smaller than atoms, the hypothetically ultimate units. Radium was found to be shooting off the same electrons, among other darts; it would take thousands of years to stagnate into lead. Transmutation! So the old alchemists were not idle dreamers! The whole theory of the atom was shaken. Something had to take its place.

Still clinging to Victorian conceptions, Rutherford gave us another machine. Under the new dispensation the atom became a solar system in miniature. In the center was a nucleus; around it electrons revolved like planets. An atom of hydrogen, which stood at the head of the table of elements, had one electron revolving around a nucleus. At the foot of the table, the ninety-second place, stood uranium, with a cloud of ninety-two electrons around the nucleus. All this worked very well for a time. Young Moseley, killed at Gallipoli, had shown the meaning of a numerical place in the table. It simply indicated the number of revolving electrons — one for hydrogen, ninety-two for uranium. That still holds.

Alas, the system was too mechanical. In accordance with Newton's laws, the outer electrons should have fallen into the central nucleus long ago, just as the planets will some day fall into the sun. On paper, at least, the whole universe had collapsed, composed as it was of atoms. Then came Professor Niels Bohr with a theory that explained admirably why suns and lamp filaments glow — something no one had satisfactorily explained before. The electrons were jumping from orbit to orbit in a very unplanetary way, thus radiating light, heat, and electric waves. When the physicists tried to follow the Victorian method of predicting how, why, and when the electrons would leap, they were baffled. Electrons ignored time and space. Or as one physicist put it: "They seem to be able to make the calculations that tell them where to jump." Cause and effect were abandoned and with them the whole mechanism of determinism. And if cause and effect ceased to reign in the atom, what of a universe made of such atoms? Cause and effect have no more place out among the stars than within the atom. The way for free will, mysticism, supernaturalism is opened. A man like Eddington finds a certain resemblance between the brain and an atom. "There is nothing in the physical world to predetermine what either will do." His reasoning is simple. If the electrons in an atom behave as if they had free will, and if brains are composed of these same atoms, have we any right to speak of determinism?

These disquieting conclusions are reached, not only because of Bohr, but because of Dr. Werner Heisenberg, enunciator of the Principle of Uncertainty. Baldly stated, the Principle holds this: A particle cannot have position and velocity at the same time. This looks innocent enough. But the Principle has made it necessary to throw the whole Victorian machine on the junk heap. An electron makes itself known by hitting a screen. It is a visible flash then. We think we have transfixed it. Nothing of the kind. In the very act of making itself visible, it has dissolved into something else. We say the electrons are particles and devise an experiment to prove it. Again, we say that they are waves. Another appropriate experiment proves that also. We merely set up a theory, create circumstances to prove it, and call ourselves "scientific." But no experiment can possibly prove that an electron is both a particle and a wave. What, then, is it? The truth is that scientific experimenting will not bear scrutiny when it reaches the infinitesimally small. The measurements break down.

In this extremity the mathematician enters. He may not be able to tell what single electrons



are doing, but he can handle them in groups. In fact, he is in much the position of a life insurance actuary who must deal with an immense block of living people, all endowed with free will. Nothing can be predicted about any individual in this block of living people, but it is possible at least to find out how old they are on the average, how long they will live on the average, of what they will die on the average, and what their habits are on the average. In other words, the actuary is concerned with probabilities, and so is the mathematical physicist when he tries to explain the mysteries of matter. Probabilities imply events. So the atom becomes, not a thing of substance, but a collection of events. Matter is something that happens. An atom is a ghostly, empty blur of leaps. All that we know about matter is now expressed in mathematical equations. They mean something to bombarders of atoms, to the Einsteins, Bohrs, Millikans, and Comptons of our time, but to the rest of us they are as meaningless as the printed notes of a symphony to a tone-deaf man. Lump by lump, shred by shred, bit by bit, we have torn a piece of the universe apart and beheld — what? Whirling, spinning, rushing electrons. Your hand touches mine, and if flesh does not melt into flesh, it is because of the forces involved in the whirling, spinning, and rushing. We try to capture the electrons singly and examine them. Are they not the ultimate reality? We see them as a flash on a screen or as patterns on a photograph, but they vanish in the act of thus capturing them. With them reality also vanished. We are left holding a set of equations. We have no right to say that all this is moonshine, that science has become irrational. Step by step, physics has been logically forced into this difficult position. There can be no return to the Victorian machine. Physics may be helpless in the face of the new mysticism, but at least it is honest.

Are Natural Laws Valid?

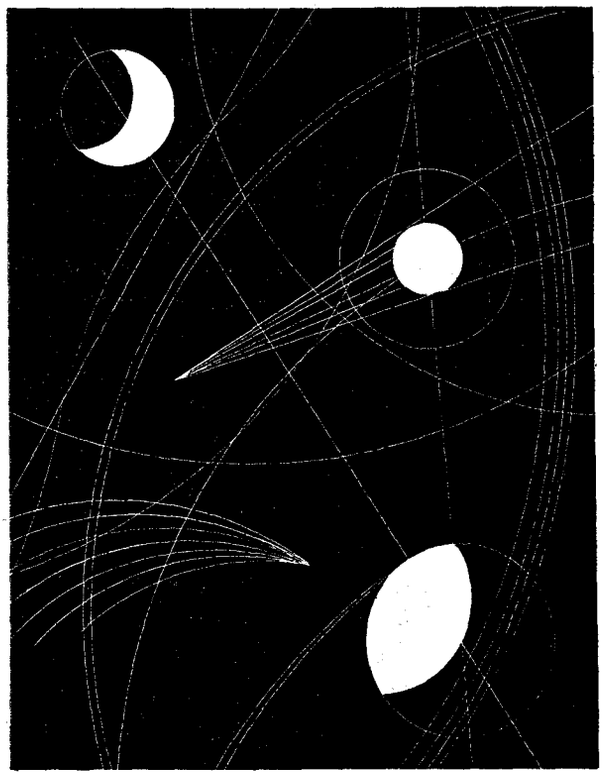
If free will reigns, what becomes of our laws of nature? They are mere conveniences, good enough for astronomers and engineers who must deal with matter and energy in the gross, but not good enough when we come to the atom and the electron — the rock-bottom of matter and reality. Not nature but the mathematicians created the laws. Throw a handful of peas into a tray. They arrange themselves in triangles that can be readily traced. It looks as if the peas had arranged themselves in obedience to a natural law. The case is so simple that we are not fooled for an instant. With the laws that have been relied upon to explain everything from the motion of the earth around the sun to the forming of a precipitate when hydrochloric acid is poured on silver nitrate, it is the same.

The very Gibraltar of physics is the famous second law of thermodynamics, which means in plain English that hot bodies give up their heat to cooler bodies, that water invariably runs down hill, and that the universe must be ultimately reduced to stagnation. Now there are doubts. Physicists are beginning to question the validity of the famous second law. It is a mere statement of probabilities. The odds are many billions to one that the sun will rise tomorrow as it has risen ever since there was an earth and a day, that a stone released from the hand will fall to the ground, that water thrown on a fire will not freeze. Hence the seeming inevitability. But remember that we deal with vast reaches of time and space in cosmical physics. The clock of the universe has been ticking only a few minutes, in a sense; each

tick an æon. What right have we to extrapolate a brief experience and to assert that it holds good in infinite time? A savage sees the rain fall on the mountains and run off into rivulets. He sees rivulets swelling into streams, and streams joining rivers and pouring themselves into the sea. But of the process of evaporation from the surface of the sea, of clouds thus formed, of precipitation from the clouds, of the whole closed cycle — of all this he is unaware. Are we higher savages similarly unable to grasp the vast processes of the universe? Do we see but one phase of a cycle? Moreover, if natural laws cannot be applied to the atom, why should they be valid in a universe built up of atoms? To men like Professor R. A. Millikan the second law of thermodynamics is as good as dead: as he has expressed it, "The Creator is still on the job." So it is with all our natural laws. They are but statements of probabilities, statements to which no exceptions have been noted in ordinary human affairs, with the result that they are accepted in practical life as finalities.

Another bulwark is the law that deals with the conservation of matter. The Victorians told us that we can change matter from one form to another — coal to ashes and gas, for example — but that we cannot destroy it. But Einstein's equations throw doubt on the law. Now there is experimental reason to believe that matter can be literally annihilated — blotted out of existence, as a collection of atoms, to become radiation. It is thus that Jeans accounts for the radiance of the stars and for their hoary ages. If the Einstein equations are correct, the process ought to be reversible, which is much like saying that the radio waves that carry Toscanini's music to us can be converted back into matter, out of which the coils and tubes of a new radio set can be constructed. The process has not been observed. On the other hand, there is evidence that mass can be converted into energy. Give a particle the speed of light, for example, and there is reason to believe that it ceases to be a particle. It becomes a photon — a light-bullet, something utterly immaterial.

It is clear that we have not only scrapped the Victorian machine universe but even the immutable laws that governed it. What of the forces that astronomers and engineers managed



to measure and even control with the aid of the laws? Mere fiction. Like the laws, they serve the practical purposes of life, but they have nothing to do with reality.

The Ascendancy of Mathematics

In order to explain the mechanics of the solar system, Kepler populated space with "intelligences," "virtues," and "animal faculties." Since everything on earth in his time was pushed or pulled by animal or human muscles, it was natural to suppose that similar agencies were at work to move heavy masses. A stone fell to the ground because it had a "virtue" that made it do so. A planet was matter, like a cart. Like a cart, a planet must be pushed or pulled by a "virtue," perhaps an invisible angel. For Kepler's "virtues" Newton substituted "forces." By discovering the relationship between masses and attractive power, he reduced the universe to what seemed to be law and order. But the "forces" were just as anthropomorphic as Kepler's "animal faculties" or the invisible angels that were supposed to push planets around. The Einsteinian universe knows nothing of forces in the Newtonian sense. A planet or a ray of light can no more help speeding on a curve than a ship on its way to Europe can help sailing on a curved

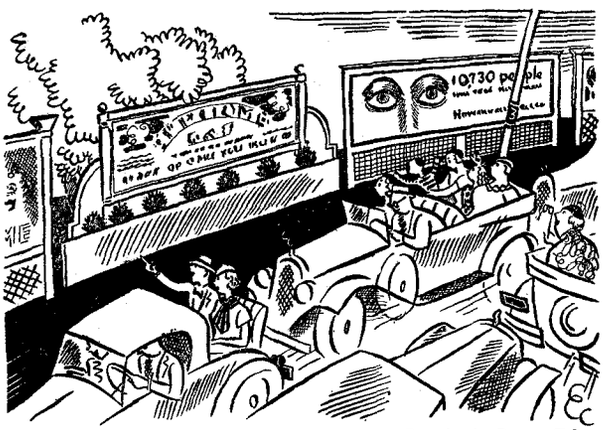
course on a spherical earth. Infinity? A mathematical convenience and nothing more. The universe is closed. It is a problem in higher geometry. In fact, more universes have been created by the mathematicians in the last ten years than the tailors have created fashions in dress coats for men.

Mathematics, not mechanics, now reigns in science. Bertrand Russell once remarked that a mathematician need not know what he is talking about. Equations are developed, not because their symbols stand for anything definite, but because they follow a natural, logical course of reasoning and satisfy a philosophic necessity. It is said that out in Pasadena, during a lecture attended by men who were his peers, Einstein chalked on a board some equation in which a strange symbol occurred. "What does that mean?" asked one inquisitive member of the audience. "I don't know," was the answer, "but it looks nice." The story may or may not be true, but it illustrates Russell's point. Out of such strange proceedings came the expanding universe. Einstein had introduced a mysterious Greek *lambda* in one of his early relativity equations. What did it represent? He inserted it merely to satisfy an esthetic, philosophic need, just as a painter puts a spot of light where it belongs to produce the desired effect in a landscape. If the mathematician need not know what he is talking about, the physicist has no such privilege. He gives the symbols a meaning. He must always know what he is talking about. As a physicist, therefore, Einstein made *lambda* stand for the "cosmological constant." What is that? Something that offsets the shrinking effect of gravitation. By giving *lambda* various values, Lemaître creates a universe on paper, a universe which explodes with such violence that an earthly detonation of dynamite seems snail-like in comparison. But is the universe like that? Drs. Hubble and Humason, out on Mt. Wilson, turn their hundred-inch telescope on the frontiers of the heavens. They actually see nebulae rushing away at the inconceivable speed of twelve thousand miles a second. It is as if the universe were a bubble that were being blown up. Every fourteen hundred million years the radius is doubled. Eddington even goes so far as to maintain that the bubble has actually burst and that millions of years must elapse before we become aware of the most terrible of all catastrophies — so vast is the space that must be bridged by light. Yet the physicists are not satisfied with the proof of the Mt. Wilson instruments. After all, the instruments are on the earth, and so are the men that manipulate them. Can we be sure that what we see here is actually occurring far, far out on the confines of the universe? May not this rushing away of the outer nebulae be an illusion? If we cannot be sure on the earth that an electron is a wave or a particle, how can we be sure of these nebulae and hence of an exploding universe? Besides, the proof is too good. It is as suspiciously perfect as a criminal's alibi. It turns out, too, that the stars are older than the universe. How can a bubble be younger than the soap-film of which it is composed? Again, we are left holding a set of mathematical equations, wondering what is the reality behind them.

Whether we analyze the atom or the universe, we deal with what Professor Levy of Imperial College, London, calls "isolates." Nature is too colossal, too complex to be grasped as a whole. The scientist must isolate aspects of it and study these separately. Only a few "isolates" can be handled mathematically or in any other way. What we have achieved, then, is merely a kind of framework. It cries out to be filled. But physics wrings its hands helplessly. It leaves out of the framework the greenness of the trees, the billowing of the sea, the stirrings of our own consciousness. With these the Victorians refused to concern themselves, yet these are now recognized as an essential part of the cosmos. The fierce belief of martyrs willing to die at the stake can no longer be dismissed because it has nothing to do with the scientific approach to the universe. Our strange flashes of insight may have a deeper meaning than we are aware. There are moments in Bach and Beethoven when the framework seems to be less empty. The more philosophical scientists are convinced that the artist and the mystic have something of importance to reveal. Accordingly, we listen for the verses of a new Lucretius singing a new *De Rerum Natura*. But we hear from poets only the ring of steel and the grinding gears of a machine, with which they have at last caught up, but which science has abandoned.

WHAT! NO BILLBOARDS?

BY JANE CASSIDY



Drawing by Barney Tobey

THERE ARE no billboards. If this affronts the evidence of your eyesight, not to mention ordinary common sense, just consult the Outdoor Advertising Association of America, Inc., which is in the happy position of having made all the rules for their particular game. Here is what they say in their little bible, *Outdoor Advertising, the Modern Marketing Force* (blue and gold, semi-limp): "The word 'Billboard' is no longer used in the Outdoor Advertising industry and is rapidly falling into disuse among those outside the industry. Instead of Billboards we now have Poster Panels and Painted Bulletins."

All this is fine and dandy — if only you could get Mrs. Jones, Mr. Milquetoast, and the rest of the public to believe it. But Mrs. Jones is a practical woman, lots brighter than she looks. If you asked her, she would probably contradict the outdoor advertising boys. "Billboards?" she would say. "Of course there are billboards. Might as well say there weren't any Tin Lizzies because they were really Model T. I may not know much about outdoor advertising, but I know what I see. The things are *there*, aren't they?"

Which, of course, is where the trouble comes in. Metaphysics cuts no ice with the general public. Some people don't like billboards — and to call them fancy names like "poster panels" doesn't mend matters a bit. Moreover, the people who really count, the advertisers and consumers, aren't interested in quibbling. Common sense is all that appeals to them, common sense and a fair return for their money. As long as billboards bring the manufacturing advertiser adequate revenue, as long as the consumer finds them useful, billboards will go on; and no longer. Meantime, nobody really cares what they call the darn things.

These are points which the outdoor advertising gentlemen do not appear to grasp. Consequently, they throw up a smoke screen of elegant verbiage, which fools nobody, when they might better be using their time in an effort to justify the billboard — if they can. Otherwise they will be licked, no matter how many synonyms they can think up.

READ AS YOU RIDE

OUTDOOR advertising, like any other advertising, is a way for the proprietor of whatever is advertised to tell the public how desirable his goods are, so that he may sell them. Now the value of any advertising lies solely in how well it can perform such service, and it begins to look as if a demonstration were due where billboards are concerned. That's what the boys should be worrying about.

Outdoor advertisements function in the same way as any other advertisements, with one important difference — the method of circulation. They do not get about themselves, like advertisements in periodicals, but sit still and let their readers come to them. They wait quietly, implacably, until their prey ventures forth, and then there they are. "It has been estimated," an outdoor advertising man once said to me in a throbbing voice, "that the average person spends four hours a day out-