DISCUSSION

THE EVOLUTION OF PHYSICS

THE term evolution may connote different ideas to different people. To the man on the street it may conjure up a monkey; to the biologist it may mean the very gradual building-up of complex forms from primitive cells; to some physicists it may suggest the breaking-up of heavy, unstable, complex atoms into lighter simpler ones, the radioactive family tree. But it may mean the evolution or the growth of ideas in physics. Even here, however, the theorist may stress one view, the experimentalist another.

Let us compare a recent book, "The Evolution of Physics," written by theorists Einstein and Infeld (Mr. A) with a book having the same title which might be written by an experimental physicist (Mr. B). It will be seen that B might claim that A's title is a misnomer. Moreover, B would take vigorous exception to some of A's views. According to A (page 33), "Physical concepts are free creations of the human mind." B believes that physicists are slaves; they are under compulsion to form concepts in accord with experimental results. He gives one notable example. Planck, in order to account for the experimental data regarding black body radiation, found it necessary to make an unwanted, a seemingly absurd assumption; namely, that radiant energy is emitted and absorbed in bundles. Thus came into existence the quantum idea, the most important concept of the past forty years, the concept now of overwhelming importance.

Again, according to A (page 9), "Human thought creates an everchanging picture of the universe. Galileo's contribution was to destroy the intuitive view and to replace it by a new one." Here it seems to be implied that our picture of the universe may be formed merely by thinking about it. But we can hardly claim that a picture so formed would necessarily have any place in the evolution of physics. Our waste baskets have received many communications presenting pictures of the universe formed by thinkers. As to Galileo nowhere in A's book is it brought out that the great contribution made by Galileo was the idea of measurement, exact measurement, and of concepts depending upon experimental evidence. According to B this idea was the foundation stone of the solid structure of physics.

B would emphasize the fact that physics is an experimental science, that its evolution has been due to the exhaustless energy of experimenters. But A seems to regard experimentation without a pre-existing theory as rather useless. Consider, for example, the statement on page 73, "It is hardly possible to imagine such experiments (electrical) performed in accidental play without the *pre-existence* of more or less definite ideas regarding their meaning." What pre-existing theory did Roentgen have regarding x-rays, the existence of which were unsuspected? Did the Curies preconceive the astounding properties of radium or vision the universe that was to be opened up by its discovery? As a further evidence that A regards the growth of physics to be chiefly along theoretical, not along experimental lines, it may be noted that the name of Rutherford—the greatest experimental physicist since Faraday—occurs only once (page 272), and the great domains which his researches opened up are ignored.

B would point out that the greatest step of all time in the evolution of scientific thought was the contribution made by Newton, who, basing his argument upon the experimental work of Tycho Brahe, Kepler and Galileo, came to the conclusion that every particle of matter in the universe attracted every other particle. No longer was the motion of a heavenly body a mystery—it was identical in nature with that of a stone falling to the earth. To vision all the particles of the universe as attached to one another by bonds which could not be altered by the interposition of other particles was to *create* a new universe.

A devotes about half his book to a discussion of two topics, the field and the theory of relativity. To the man on the street the term field may mean a plot of land, perhaps enclosed by a fence. But A develops at length the Faraday-Maxwell picture of a field as a region in which forces exist, a region of energy due to masses or electric charges. This point of view was a very prominent one in the physics of the later decades of the nineteenth century. It was taught that the important feature of an electric current resided not in the wire but in the region outside of the wire, in the field due to the current. It was rude, rather indelicate, to ask what an electric current is, one should not attempt to form a picture of a current, one should emphasize the importance of the field. Then came the discovery of the electron, and an electric current became a procession of electrons. The mechanical view, the old electric fluid (atomized, modified) returned. The concept of the field remained, but it no longer excluded an inquiry into the nature of its origin.

B would give small space to the theory of relativity. He would point out that, so far, it has played but a small part in the great growth of physics. The one notable relation concerning the increase of mass with speed, which is frequently spoken of as the relativistic relation, was derived by Lorentz, as were also the transformation equations connecting time and space for moving axes. The equivalence of mass and energy can be derived at once from the Lorentz relations. All these relations are also outstanding results of the relativity theory and are thought by many to justify our attaching importance to that theory, but it is seen that they may be regarded as having another and earlier origin.

A devotes about one sixth of his book to modern physics, including the quantum theory—the outstanding theory of our time. B would give the major portion of his book to modern physics. The discovery of x-rays in 1895—what a burst of scientific activity followed! It is frequently stated that this discovery was accidental—but it was no accident that Roentgen was trying to find more facts connected with the discharge of electricity through a very rare gas. The discovery of x-rays led (1896) directly to that of the Becquerel rays from uranium; this again led (1898) directly to the discovery of radium. In the meantime (1897) the electron was discovered by J. J. Thomson, but its clear identity was not established without using the property of x-rays in ionizing a gas.

X-rays, the electron, radium—what a new world came into being! The atoms of chemical elements hitherto indivisible, indestructible units, definite for every element, had at least common constituents, electrons. But Rutherford and Soddy, working with radium, set forth the view that the radioactive, also the heaviest, atoms shot out either helium atoms or electrons and were thereby transformed into atoms of their chemical neighbors. Natural transmutation of the elements undreamed of before the present century, even by alchemists, came into our vision.

In the meantime, another line of experimental work had established certain laws regarding radiation from a hot source. To satisfy these laws Planck (1900) found it necessary in his theory to introduce the idea that radiant energy was tied up in bundles. The experimental physicist (B) would place great emphasis upon the quantum theory, for practically all phenomena are in accord with it. To change our point of view regarding radiant energy from being a phenomenon of continuity to one of discontinuity, from being one of wave motion to one of atomicity was to bring about one of the most important steps in the evolution of physical thought.

The chapter dealing with the evolution of our ideas regarding an atom would be a very long and important one in B's book. It would begin with the post-Dalton pre-electron atom, the perfectly elastic sphere (?), the atom which accounts for the properties of gases, it would continue with the post-electron pre-nuclear atom, the pumpkin atom, then with Rutherford's great contribution, the nuclear solar system atom, with the atom of definite energy levels initiated by Bohr. Here the evidence regarding energy levels becomes bewildering in its complexity, the evidence brought out by atomic spectra due to visible radiation, infra red, ultra violet, x-rays. If B would continue with the arrangement of atoms in molecules, as evidenced by molecular spectra, the Zeeman and Raman effects—this chapter might become a volume.

B would necessarily give space to the exceedingly accurate measurement of the mass of an atom, by Aston, Dempster and others, to the evidence that an element may have several different kinds of atoms, that besides the outer electrons the nucleus, minute in size, must contain protons (hydrogen nuclei) and neutrons and that the atoms of an element differ only in the number of the neutrons, the atoms of different elements only in the number of protons. That expulsion of a proton or a neutron may be brought about by atomic projectiles—that we may have artificial transmutation and radioactivity. No alchemist in his wildest moments even dreamed of all of this!

B would necessarily point out that the enormous growth of our ideas in modern physics is due to techniques and experimental devices which have done for modern physics what the telescope did for astronomy, the microscope for bacteriology, the spectroscope for all sciences. The outstanding modern devices are the Wilson cloud chamber, which enables us to see the path of an atom or electron, the electrometer, the Rutherford-Geiger-Müller tube, which has extended our ability to measure small electric currents (one electron a minute) a millionfold, the Lawrence and Livingston cyclotron, which enables us to hurl atoms about as in a sling shot with enormous speeds. And the electron tube—what has it not done for all science and human relations; the amplifier that has made possible the measurement of minute currents in the brain, the oscillator that generates electric waves of all frequencies, the device that has made possible instantaneous intercommunication between all peoples on this earth, the necessary component of a thousand modern devices—has it no place in the evolution of physics?

So physics, starting with Archimedes' lever and with the extremely limited world of the tangibles, has reached out "farther than ever comet flared or vagrant stardust swirled" and has bored into the minutest realms which the mind can picture. Always rigid and exacting, it has led the human race into our modern fairyland.

GORDON FERRIE HULL

DARTMOUTH COLLEGE

FOLSOMOID POINT FOUND IN ALLUVIUM BESIDE A MAMMOTH'S BONES

UNDER conditions similar to those of other recently reported finds[1,2] mammoth bones and a Folsomoid

[1] J. D. Figgins, *Proc. Colo. Museum Nat. Hist.*, 12: 2, 4–8, plates 1–2, 1933.

[2] E. H. Sellards, *Bull. Geol. Soc. Amer.*, 49: 999–1010, plates 1 and 3, July 1, 1938.