QUOTATIONS

THE GIANT CYCLOTRON[1]

WITH so much creative human talent employed in devising increasingly powerful engines of destruction it is at least some comfort to know that to-day in the United States work is proceeding on two of the mightiest instruments the world has seen for the peaceful exploration of the universe. One is the 200-inch telescope nearing completion on Mount Palomar, California; the other is the giant cyclotron under construction at Berkeley, California. The new telescope will explore the outer reaches of the universe, the realm of the infinite; the new cyclotron will probe the inner reaches of the universe, the realm of the infinitesimal. The telescope was made possible by an appropriation in 1928 of $6,000,000 by the International Education Board, established by Mr. John D. Rockefeller, Jr. This last year the Foundation appropriated $1,150,000 to the University of California for the construction and housing of the cyclotron.

From the time of Democritus, the natural philosopher has tried to probe inside the matter of which our physical universe is built in order to discover the nature of its smallest parts and the laws which govern them. For centuries there could be nothing but vague speculation, for suitable experimental procedures were not available. But brilliant advances have been made since the turn of the present century, and in forty years of research a flood of light has been thrown on the nature of atomic structure. Two decades ago this inner citadel of the universe was successfully attacked by shooting into the atom small projectiles of such high speed that they disrupt the internal pattern. Then from a study of the erupted fragments, of the mutilated remainder, and of the battered projectile, new knowledge was obtained of the atom's structure.

The most successful device for this purpose has been the cyclotron, invented by Professor Ernest O. Lawrence, of the University of California. In essence the cyclotron is a machine for imparting extremely high velocities to atomic particles by means of electrical impulses. The particles, which are the bullets of the gun, are charged atoms. Whirling in ever-widening circles in a chamber mounted between the poles of an immense magnet, these particles are sped faster and faster by alternate changes of an electrical field from negative to positive and vice versa until they are finally shot out through an opening to smash against a target whose atoms are to be cracked by their impact. It is as if a stone were whirled on the end of an elastic cord in a constantly enlarging orbit until at last it flies off at a tangent with tremendous force. When these bullets emerge from the cyclotron they are in the form of a steady beam, moving at velocities which may exceed 100,000 miles a second. At such high speeds they constitute the most powerful concentrations of energy ever controlled by man.

There are now in operation throughout the world some thirty-five cyclotrons of varying sizes. Of these, twenty-four were either built by, or are now being operated by, men who were trained in Lawrence's laboratory. Lawrence himself has built a sequence of cyclotrons of increasing size, varying in weight from 500 pounds to some 220 tons, and producing a beam ranging from 80,000 volts in his smallest cyclotron to 16,000,000 volts in his largest. The new giant cyclotron will contain over 4,000 tons of steel and copper in its magnet alone and will produce a beam whose voltage will range from 100,000,000 to perhaps 300,000,000. The beam of the largest cyclotron now operating penetrates, in air, about five feet; the beam of this giant instrument will penetrate 140 feet.

But of what use is this machine and what can it do for man? The chief practical application to date has been in the use of the beam to produce radioactive matter. The new array of radioactive substances which has resulted will almost surely have an important relationship to current scientific problems; but one broad field of application has already been clearly demonstrated: these artificially radioactive atoms are the familiar "tagged atoms" which are now being used in chemical, biochemical, physiological and other laboratories all over the world in a wide range of basic research which would be quite impossible were it not for this unique new material.

Furthermore, the beam of exceedingly high-speed particles can be applied, like x-rays, gamma rays, and other types of radiation, directly to living organisms, and the effects can be analyzed and ultimately utilized. It will require years to investigate the efficacy of beams of different composition and intensities on various vital processes; but experiments have already shown, for example, that beams of neutrons can penetrate deeply into living tissue and can there release local radiations which can be, but need not be, intense enough to kill cells. These further applications are now in their first tentative stages. It is as difficult to predict the exact nature of their use as it would have been in the case of x-rays at a similar point in their development.

But if these results are being obtained by cyclotrons now in existence, why build this new giant machine? The answer takes us into the field of ex-

[1] From the President's Review of the work of the Rockefeller Foundation for 1940. Raymond B. Fosdick.

ploration and the insatiable intellectual curiosity which is the mark of civilized man. The most powerful cyclotrons now in existence produce particles whose speeds, when fired at atoms, enable them to knock off only the external and more loosely bound features of the atoms under attack. It is at this point that the new giant cyclotron, now under construction, is of critical importance, for it is designed to produce projectiles so powerful that they can penetrate and explore the nucleus itself.

It is essential to realize the significance of this point. During the last forty years, science has learned much about atomic structure. One outstanding mystery, however, remains, and in many senses it is the major mystery. Relatively little is known about the nucleus, the central core of the atom. There is evidence that this nucleus possesses a discoverable structure, that it is formed of certain elementary units in accordance with laws with which we are not familiar; and physicists to-day consider its investigation the most important present problem in physical science. Here in the interior of the nucleus is the one essentially unexplored part of our universe. It is a world into which we have hitherto been powerless to enter; and the urge to penetrate, to explore and to analyze is irresistible.

This urge, moreover, is heightened and justified by the conviction that this virgin territory will prove to be rich. Practically all the energy of the atom, for instance, is stored within the nucleus; and it is the nucleus which really determines the character of an atom and is hence ultimately responsible for all the properties of matter. Furthermore, there is evidence that the essential forces which bind the nucleus together are due to an elementary particle called a "mesotron." These same mesotrons play an important rôle in cosmic rays; and if more could be learned about mesotrons it would immediately throw light not only on this other perplexing problem, but on still further riddles with which science is now grappling on the frontiers of knowledge.

The real case for building a great cyclotron rests upon its ability to make accessible a new infinitesimal world—the interior of atomic nuclei, with all the possibilities of fresh knowledge that may there reside. It is an adventure in pure discovery, motivated by the unconquerable exploring urge within the mind of man.

In this sense, therefore, the new cyclotron is more than an instrument of research. Like the 200-inch telescope it is a mighty symbol, a token of man's hunger for knowledge, an emblem of the undiscourageable search for truth which is the noblest expression of the human spirit.

SCIENTIFIC BOOKS

HUMAN NATURE

Human Nature and the Social Order. By E. L. THORNDIKE. xx + 1019. Macmillan. 1940.

THIS book is of monumental proportions with its half million words and weight of nearly 3½ pounds. Because of its forbidding size it lay on my desk for weeks before I could muster courage to tackle it. Once started, however, I read the book from cover to cover with unflagging interest in the contents and with many chuckles over the author's way of putting things. My chief complaint is that it was not published as two volumes instead of one, so that it could be read by the nearsighted with less fatigue of the arms and shoulders.

The material is divided into 38 chapters and 6 appendices. Part I (400 pages) deals with such topics as the ABC of behavior, human abilities, wants and their measurement, mental dynamics, individual differences, the roles of nature and nurture, conflicts of wants and the evaluation of satisfactions. Among the leading problems treated in Part II are the science of philanthrophy, the welfare of future men (eugenics), the welfare of the present, utility and disutility, natural resources and capital, labor and management, buying and selling, payment for human factors, money and credit, ownership, the psychology of capitalism, political science, human relations, criteria of a good government, rulers and methods of ruling, the aims of government, human nature and the law, the improvement of law, human nature and reform.

A statement in the preface says that the book is intended not only for college students of the social sciences but also for thinking men and women generally. In my judgment it will be useful and stimulating to both groups despite the fact that it is neither a systematic treatise on social psychology nor an all-round introduction to the social sciences. Part I is an exposition of the facts and principles of psychology which the author considers most important for the social science student. Here 75 pages are devoted to abilities, 55 to individual differences, 125 to wants and mental dynamics, 57 to heredity and environment and 50 to evaluation of satisfactions. In these sections the author draws extensively upon his earlier books, but there is much new material and the old is effectively reorganized and freshly stated. Part I presents a large amount of psychological information of the kind social scientists most need but get little of from the average text-book in social psychology. The