MILLIKAN SEES WORLD REMADE BY USE OF SCIENTIFIC METHOD

Modern Civilization and Altered Human Outlook Are Traced by The Great Scientist to Substitution of Facts for Fancies

The changed world that the modern scientific method has brought about since Galileo's epoch-making innovation was dealt with by Dr. Robert A. Millikan, Nobel Prize winner, in an address before the Phi Beta Kappa alumni in New York City last Tuesday night. Dr. Millikan's discussion of this subject, taken from his address, follows.

From an Address

By ROBERT A. MILLIKAN.

THE most essential contribution of science to the intellectual life of the past century lies—to put it in one phrase—in the discovery of the scientific method. I think there can be no shadow of doubt that the great characteristic feature of our times, the one thing that does distinguish our civilization from all that have preceded, is this discovery of the scientific method and the results that have followed upon its application. That discovery was indeed not made in our generation. It was made some 300 years ago, but its cumulative effects have come only within the last century.

But now just what is the scientific method that I talk about, and what was the change in mode of approach that Galileo so conspicuously employed and which resulted in what Professor Whitehead calls "the most intimate change in outlook which the human race had yet encountered"?

Facts Resorted To.

The method consisted in not starting at all with a priori postulates about the nature of reality, or with any complete philosophic systems, such as all the philosophers of the ancient world, idealists and atomists alike, had started with and indeed had quarreled interminably over; in discarding likewise all intuitive axioms on the one hand and authority on the other such as had been the foundation of the medieval scholasticism of Thomas Aquinas and of his successors; and appealing by the experimental method, as Wetham says in his new "History of Science," "to the tribunal of brute facts, facts which bore no relation to any philosophic synthesis then possible. Natural science may use deductive reasoning at an intermediate stage of its inquiries, and inductive theories are an essential part of its procedure, but primarily it is empirical, and its ultimate appeal is to observation and experiment.

"It is not too much to say that Galileo started modern physical science on the course which has extended unbroken through our own day. In a very real sense, he is the first of the moderns. As we read his writings, we instinctively feel at home. We know that we have reached the method of experimental science which still is in use today. The old assumption of a complete and rationalized scheme of knowledge has been given up. Facts are no longer deduced from, and obliged to conform with, an authoritative and rational synthesis as in scholasticism; no longer are they even given meaning thereby as they were in the mind of Kepler. Each fact acquired by observation and experiment is accepted as it stands, with its immediate and inevitable consequences, irrespective of the human desire to make the whole of nature at once amenable to reason.

"Concordances between the isolated facts appear but slowly, and the little spheres of knowledge surrounding each fact come into touch here and there, and perhaps coalesce into larger spheres, but the welding of all knowledge, scientific or philosophical, into an all-embracing unity, if not seen to be forever impossible, is relegated to the distant future. Medieval scholasticism was rational; modern science is in essence empirical. The former worshiped the human reason acting within the bounds of authority; the latter accepts brute facts, whether reasonable or not."

Galileo, unlike some who followed him and founded systems upon his work, like the French encyclopedists of the eighteenth century, "was content to wait in acknowledged ignorance upon questions that can only be answered by rash speculation or deduced from philosophic systems. He confessed that he knew nothing about the nature of force (though he had studied it all his life), the cause of gravity or the origin of the universe. Rather than express extravagances, he declared it better to pronounce that wise, ingenious and modest sentence, 'I know not.'"

Now, that is the scientific method. What has resulted from its application?

First, practically the whole of modern material civilization in so far as it differs from ancient civilization. It is easy to trace the pedigree of practically every modern industrial or scientific device back to the new knowledge which has come from the application of Galileo's method, and, indeed, from his own experimental researches.

Let me take two illustrations. For thousands, perhaps for tens of thousands of years, we do not know how long before his time, men had pushed carts and pulled wagons, but not one of them had any correct idea about the actual relations between the force exerted and the motions produced. That was just what he found by studying the way his marbles acquired velocity as they rolled down his inclined plane. Without the formula which we in elementary physics call f=ma force is equal to mass times acceleration, without that formula which came into the knowledge of mankind through his work, not one single steam engine, automobile, airplane, or any other power machine could be designed today.

Gravitation Explained.

Further, it was precisely this formula, as everybody knows, which seventy-five years later, in the hands of Newton, made the discovery of the law of gravitation possible, because it was simply by equating what he got from that formula, as applied to centrifugal motion, to the results of the inverse square law that he found the explanation of the moon's motion.

And with that law has come the whole development of celestial mechanics, for obviously you cannot even make a start in celestial mechanics without that law, and it is the successes of celestial mechanics which have at last weaned the whole world away from treating with anything but ridicule—to use Kipling's phrase—"the village that voted the earth was flat, flat as my hat, flatter than that," and opened the eyes of the world to the glories and mysteries of modern astronomy.

Take one other illustration: Through hundreds of thousands of years, alike in the epochs of savagery and barbarism, and in those of amazing Greek and Latin civilizations, man had warmed himself at his camp fire and at his grate without ever stopping to wonder what heat was; or, if he wondered, without having any idea of how to set to work to find out. More than that, it was impossible for him to find out before the idea or concept of the energy of molecular motion had been formulated, and this idea came from Galilean and Newtonian mechanics.

I do not know how many of you Phi Beta Kappa men know that the word energy as a precise physical concept was not in the English dictionary until about 1850. When Helmholtz wrote his remarkable essay in 1847—and this was one of the essays that set the principle of conservation of energy going—in the title of this essay he confused two ideas, those of force and energy, which we would not allow a sophomore in a high school to confuse today. I mention it to show that the idea of energy had not been formulated and crystallized by the middle of the nineteenth century.

Molecular Motion.

Now, it was absolutely impossible to begin to get the idea of the relations between heat and work before the concept of kinetic energy of molecular motion as an exact physical concept had been created, and that was not until about that time. It was an analytical thing which came directly from Galilean and Newtonian mechanics. It came directly from the work of Galileo and Newton, who had laid the foundations for the development of the modern steam engine; and the steam engine, in its turn, begot the internal-combustion engine. In exactly the same way through the work of Franklin, Volta, Faraday and Maxwell, all utilizing the method and the results of their scientific ancestors, has the age of electricity within my own lifetime been ushered in.

Also the same method applied to the study of the earth's crust, with its fossil records of age-long development from lower to higher biological forms, and the further study of the anatomical relations between these forms have brought to light brute facts which must tell their own tale, no matter what preconceived philosophies or world systems they may encounter.

This whole group of observed facts about the universe around us is what I think is responsible for the enormous change in human outlook that has been characteristic of our century.

In that sentence I have touched the second advance, much more important than the material one which I have been talking about, which has come into human thought and life as the result of the application of the scientific method.

Old Concepts of God.

Let me follow the idea a little further. As I read history, through all primitive thinking, and some of it not so primitive, nature is regarded as essentially capricious. Things happen because the god of the mountain or the god of the forest or the god of the river or of the sea wills to have them happen, and that god is usually endowed, too, with all human frailties. That god's will can be supplicated, pleased, enraged, appeased, cajoled, but that it operates in any systematic way or in accordance with fixed principles which man by study can come to understand, that was an idea which, while it was adumbrated indeed in the Greek world, notably in the work of Aristarchus of Samos, Archimedes of Syracuse and Hipparchus of Alexandria, was, after all, practically without influence in human life, before the real advent of the scientific method in the sixteenth and seventeenth centuries.

Galileo, in establishing the laws of force and motion, assumed the principle of uniformity and laid down regularities or laws which made prediction of astronomical events and of some terrestrial events a possibility. The continued and ever-increasing success of these predictions soon began inevitably to change man's thinking about the fundamental nature of the universe.

With increasing knowledge man's ideas of God, the integrating factor in the universe, of course began to change. The days of child-like anthropomorphic Santa Claus-like conceptions began to draw to a close, and mankind began to move forward to a more satisfying conception. The God of caprice and whim began to be replaced in human thinking by a God who rules through law. A universe which was not worth knowing because it could not be counted upon—or in Plato's philosophy because it did not exist, because with him ideas were the only reality—began to be replaced by a nature which is dependable and to some extent, at least, understandable, even controllable by man. Man began to be no longer merely a plaything in the hands of a blind fate or of a capricious Deity. Rather he began to become himself a vital agent in the march of things.

And with that changed conception, ideas of duty and therefore of religion began to change. In the old days men had made a wholly artificial and irrational distinction between the natural and the supernatural. Events which were sufficiently common and familiar were thought of as natural, and events which were uncommon and not understood were called supernatural. The idea of the uniformity or repeatability of events abolished completely all such child-like distinctions. All events without exception are worthy of study and of attempts at understanding, because nature is assumed to be dependable, not at all capricious—familiarity or unfamiliarity has nothing to do with it. Call all events natural, if you will, or supernatural, if you prefer, but forget—so says Galileo's method—either one term or the other. No wonder Whitehead called it "the most intimate change in outlook the human race had yet encountered." That is what has brought about this stupendous change in outlook of the past century, at least as I see it.

Now this group of ideas, of course, did not spring into existence spontaneously about 1600. It did, however, begin to influence human life and conduct about then, and it has influenced them most profoundly since the very recent development that is characteristic of our century of the means of dissemination of ideas. These ideas had a history, too, which goes back of 1600, for practically all ideas and all movements have a pedigree. Those ideas were themselves begotten by what is properly called the humanistic movement, which historically just preceded them—so that you can put the whole credit for it upon humanism, if you will—for this constituted the essential spirit of the Renaissance, a spirit, under the stimulus of which men, beginning about 1350, especially in the city-States of Northern Italy, sought to recover, after the period of medievalism, the freedom of classical thought and the other cultural and humanizing influences of Greek and Latin civilizations.

It was especially after the capture of Constantinople in 1453 that Greek teachers, Greek manuscripts and Greek ideas began to flood Northern Europe, and thus the language and the spirit of ancient philosophy and science became familiar to Western scholars. It was because of this so-called humanistic movement that Copernicus, Leonardo da Vinci and Galileo became thoroughly familiar with, indeed, very careful students of, the work of Archimedes and of his Alexandrian contemporaries and successors. So that modern science itself unquestionably owes its very birth to humanism.

AMERICAN SCIENTIST AND S

Times Wide World Photo.

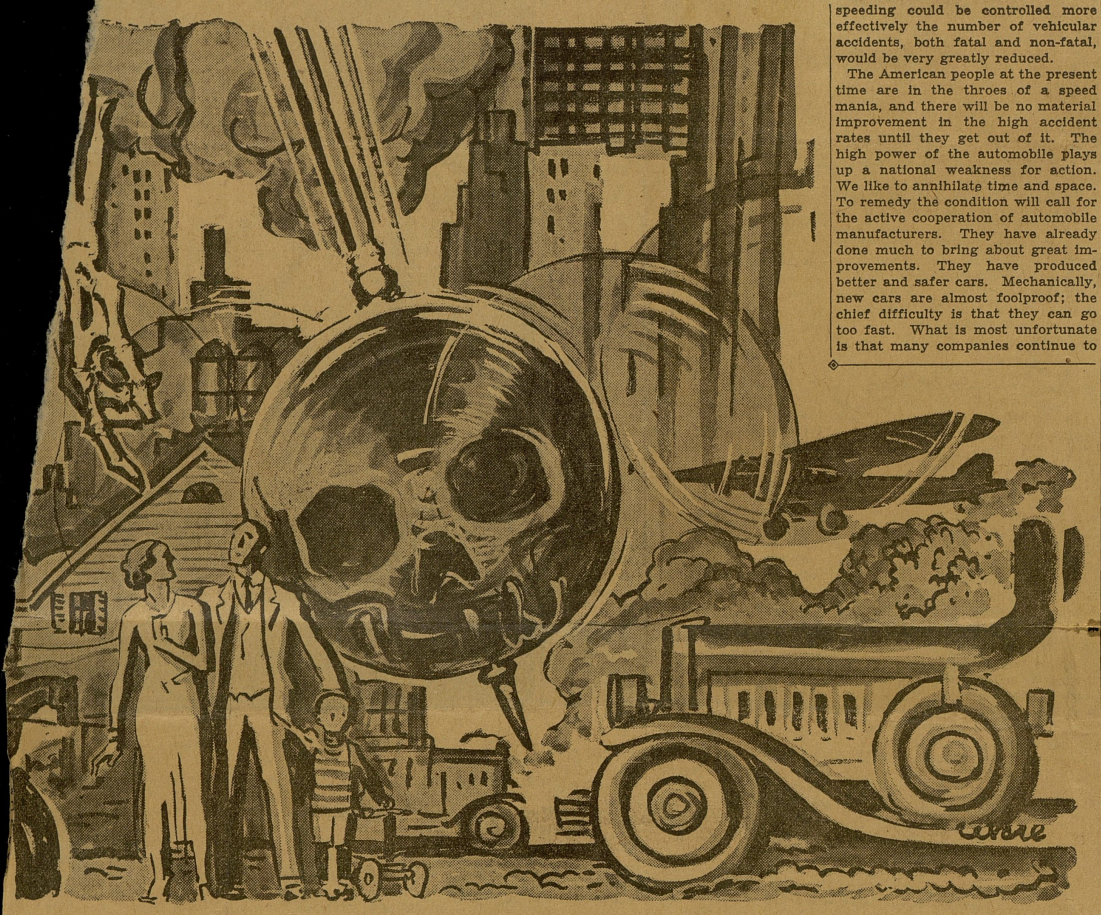
Dr. Robert A. Millikan of Pasadena.

REVOLVING FRENCH SOLAR

THE NAVY'S NEW AIRPLANE CARRIER

ACCIDENTS ATTAINS A NEW PEAK

of Crippling, Dependency and Destitution in This Country—30 to Speed in Cars, Carelessness in Factories and Homes



est Single Cause of Crippling, Dependency and of Destitution Among the People of the United States."

place of accident occurrence, the situation is reversed. This situation is obviously the result of the fact that many who are injured in automobile accidents in the open country are taken to the nearest city hospitals for treatment and die there.

As between the cities, we find a number with outstandingly high rates as, for example, Atlanta, Cincinnati, Cleveland, Columbus, Erie, Pa.; Los Angeles, Oakland, San Diego, Cal., and Wilmington, Del. On the other hand, a number of large cities such as New York, Boston, San Francisco and Washington, D. C., show much better conditions. Some, like Camden, Duluth, Milwaukee, New Orleans, Philadelphia and Seattle, occupy an intermediate position between the high and low figures. Generally speaking, the smaller cities (population under 100,000) show better conditions than the larger ones (over 100,000 population).

Improvement in Some Cities.

Some improvement in the automobile accident situation has been made in a number of cities in recent years. The United States Bureau of the Census reports that for the fifty-two-week periods ending Nov. 2, 1929, and Nov. 1, 1930, the total death rate from automobile accidents occurring in seventy-eight cities in the United States declined from 20.6 to 20.3 per 100,000 popula- Approximately one-half the

ings or took steps to make them safer; four added to the number of safety islands or safety zones, two increased the number of one-way streets. In eight cities, the officials state that there was stricter enforcement of traffic regulations last year, with special emphasis upon such important items as increase of traffic officers at heavily traveled intersections during peak hours, additional motorcycle men, drives against improper lights, &c.

In several cities the officials have realized the value of publicity in their campaigns against automobile accidents. Successful efforts were made to obtain the interest and cooperation of the press, and three municipalities delegated traffic officers, or officials, to lecture on safety before civic or fraternal organizations. One city used the radio, while another employed billboard publicity and distributed safety literature. Safe driving contests, with prizes, were featured by one city.

One city adhered to a policy of strictly enforcing at all times a "workable traffic ordinance." The officials report that, as the result of a long period of education and enforcement, pedestrians are cooperating in obeying the traffic lights.

Other safety measures mentioned include removal of trees or shrubs obstructing the view at intersections, brake-testing weeks and drives for safe brakes, and cooperat

where pedestrians are relatively few, the proportion of pedestrian accidents will decline and the proportion of collisions between motor vehicles will increase and become the leading group in the future.

It is of interest to see what the pedestrians and the drivers were doing at the time of the accident. Thus the report discloses that 27 per cent of the pedestrians received their injuries while crossing the street at intersections having no signals; another 27 per cent while crossing the street between intersections; 17 per cent were struck by motor vehicles while at play in the street and 9 per cent were crossing the street in violation of traffic signals; the remaining 20 per cent of the cases covered a variety of circumstances.

Faults of Drivers.

In the same way the figures show that in 32 per cent of the cases the driver did not have the right of way when the accident occurred; in 16 per cent he was exceeding the speed limit; in 16 per cent he was on the wrong side of the road; in 11 per cent he drove off the roadway, and in 9 per cent of the cases he failed to signal.

It is clear, therefore, that there is no single explanation for the present accident situation. In some cases the fault is clearly with the injured pedestrian. In more cases the difficulty can be traced to the driver or to a defect in the mechanism of his car. In some instances the fault is in the defective condition of the road. In others no particular cause can be elicited from the record, the accident having resulted from what one might call sheer chance. But if one item were chosen as more important than any other in the analysis of the situation, it would be the desire to speed. There can be no question that herein lies the heart of the problem. I

speeding could be controlled more effectively the number of vehicular accidents, both fatal and non-fatal, would be very greatly reduced.

The American people at the present time are in the throes of a speed mania, and there will be no material improvement in the high accident rates until they get out of it. The high power of the automobile plays up a national weakness for action. We like to annihilate time and space. To remedy the condition will call for the active cooperation of automobile manufacturers. They have already done much to bring about great improvements. They have produced better and safer cars. Mechanically, new cars are almost foolproof; the chief difficulty is that they can go too fast. What is most unfortunate is that many companies continue to advertise speed as a feature of their product. This injects an entirely false and unnecessary emphasis which makes for accidents.

Let us hope that this condition will likewise be remedied, and that the power and resources of this immense industry will be used constructively to develop the right state of mind among users of automobiles. The further growth of the industry can go on only as it respects the rights of others, and especially of pedestrians, as a condition necessary to the operation of cars.

Safety Attitude Needed.

In the meanwhile it is clearly the function of authorized authority to do generally what has already been so clearly demonstrated as feasible in a number of communities. What Milwaukee, Grand Rapids, Boston and other cities have done to control traffic all communities must do. Only a beginning has been made in this direction. The wide extension of mechanical traffic signals and of routing traffic over through highways carries with it large possibilities. The regular inspection of cars for mechanical defects prevents many accidents. In the cities much will depend upon the education of the public and especially of children to use the streets properly. This raises the question of the neglect of recreational facilities for children so general in our cities. Where but on dangerous streets can children play unless such safe recreational facilities are provided?

But more and more the safety concentrated in the

will require the full cooperation of all interested parties—the traffic officials, the drivers of cars, the automobile manufacturers and the general public.

As already indicated, there are not less than 23,000 and there may be as many as 25,000 industrial fatalities each year, together with 3,000,000 cases of non-fatal injuries received during the course of employment. It is conservatively estimated that the money losses from this source total more than a billion dollars a year. It is encouraging to find that industry has during the last ten or fifteen years realized its responsibility to remedy this situation. The larger industrial organizations especially are making forward steps in minimizing the hazards of their particular field.

Safety Systems Proved.

The United States Steel Company and the du Pont de Nemours Company have established an excellent record for themselves in curtailing accidents, and their experience shows what can be accomplished by industry generally. A new profession of safety engineer has been developed whose business it is to eliminate one hazard after another from the life of the worker. A careful record system has been developed which serves to locate the problem and to help control it. The country-wide adoption of compensation insurance has likewise had a beneficent effect in that it makes it profitable for employers to reduce the cost of their accidents.

Nevertheless, there are very serious problems involved in the industrial accident situation. Our rates are very much higher than anywhere else in the world. Coal mining and metal mining in the United States are extremely hazardous operations. The smaller shops and factories likewise seem scarcely to have waked up to the importance of industrial safety. There is clearly much to be done. But it is encouraging that at least in this field of accident prevention, there is little or no division of opinion as to the seriousness of the problem or as to the ways to solve it. More will be accomplished when the great body of workers are themselves convinced of the necessity of caution and learn how to cooperate with their employers in safety practices.

Domestic Accidents.

Possibly the most discouraging aspect of the whole accident situation in the United States lies in the home. This haven of peace is, in fact, a very hazardous place for the average woman and child. Twenty-three thousand fatalities and perhaps as many as 5,000,000 injuries attest to the seriousness of the situation. In fact, the total loss is greater than in industry or on our highways. What makes the situation particularly bad is the utter lack of organization through which the great mass of American homes can be reached. Fatal home injuries fall into four principal categories. Falls are the most important, with 8,000 deaths a year. There are 5,400 deaths from burns, scalds and explosions, and there are 3,600 asphyxiations and 2,000 fatal poisonings.

A Call for Ingenuity.

It is time that American ingenuity and inventiveness began to express itself in safety devices for the American home. An extraordinarily rich field awaits those who concentrate in this line of public service. In the last analysis, the mother is the key to the situation. She will somehow or other have to be reached and instructed in the methods of home safety, in the use of safety appliances, and in the exercise of caution. An outstanding need at the present time is for more information on where and under what condition these domestic accidents occur. For the present, at least, those who are interested in this field are working in the dark.

The safety problem stands out as

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IRCULATION figures of th

JEANS AT PRINCETON PAINTS COSMIC FEUD

Electrons and Atoms, Rushing at Each Other, Will Bring End of Universe, He Says.

SEES ALL THINGS AS WAVES

Bottled Up, They Are Matter, Freed, They Are Radiation, He Holds, Citing Swiss Findings.

From a Staff Correspondent of The New York Times.

PRINCETON, N. J., May 22.—Sir James Jeans, who, with Sir Arthur Eddington, a fellow-scientist, has been the most outspoken champion of the theory of the ultimate doomsday of the universe, presented tonight before members of the physics department and the Princeton Chapter of the English-Speaking Union what he said was further evidence that matter was being annihilated constantly in the depths of interstellar space and that the stars were slowly dissolving into radiation, never to become matter again.

The tendency of modern science, Sir James declared, was to resolve the whole material universe into two kinds of waves—bottled waves, which appear in the form of what we call matter, and unbottled waves, which we call radiation of light.

Nature's processes consist in the unbottling of these waves, or in turning of matter into radiation. Once a wave is "unbottled" there is no power in the universe to put it back in the bottle again, he said.

Bottled waves, or matter, according to Sir James, travel much slower than unbottled waves; but when an atom of mater becomes unbottled it travels with the speed of light, or 186,000 miles a second.

Explains Details of Theory.

However, while the speed of all radiation is the same, penetrating power varies according to the atoms from which the waves come, Sir James said. The more penetrating a wave is the shorter is its wave length. Thus, just as it is possible for the physicist to determine the weight of a bullet penetrating a body of water by knowing the speed of the bullet and the depth to which it penetrates, so he can determine the corresponding weight of an atom if he knows the speed of the radiation and the depth to which it penetrates.

This is exactly what has recently been accomplished by a Swiss scientist, Dr. E. Regener, in his experiments with the penetrating power of the cosmic ray near Lake Constance, Sir James said.

Dr. Regener's figures, Sir James said, correspond very closely to the figures obtained by himself by mathematical calculation on the kind of radiation that would be released by the annihilation of a helium and a hydrogen atom, respectively. The similarity of figures might be a mere coincidence, he declared, but thought this was unlikely.

On the other hand, the lecturer said, there was no evidence of any kind to prove the correctness of the theory of Dr. Robert A. Millikan that the cosmic rays were the result of the creation of new matter out of radiation in the interstellar spaces, and that they indicated a "Creator still on the job."

A mathematical analysis of the facts of astronomy, he continued, suggested that the process of atomic annihilation would probably be spontaneous—if so, this process would not be limited to the hot interiors of stars, but ought to be in progress wherever sufficient astronomical matter exists. In its simplest form, he said, the process would consist of the simultaneous annihilation of a single electron and a single proton, or a hydrogen atom. They rush toward each other at ever-increasing speed until they finally coalesce, their electric charges then neutralizing each other and their combined energy being set free in a single flash of radiation, known as a photon.

Einstein has shown how mass can be transformed into energy and vice versa, said Sir James. The combined mass of the proton and electron is equal to the mass of the hydrogen atom. If the hydrogen atom is really annihilated then the energy of the photon, a unit of radiation, should equal the mass destroyed. It is just that, Sir James contends, that the most recent figures of the Swiss scientists would seem to prove.

"This means," Sir James concluded, "that the material structure of the universe is disappearing and that the stars are slowly dissolving away into radiation, so that it is only a matter of time when the universe will wear away; and while this theory must be put forward very tentatively indeed, it is so far the only one that could offer any logical hypothesis for many astronimical phenomena."

which he gave his last full measure of strength, is pointing the way to world stabilization and world peace. Is it not regrettable that in the midst of these great deliberations, America, the hope of the world in the World War, remains isolated, mute and motionless, and stands coldly indifferent to the voices of deep distress that call to us to take our proper place in the councils of the world?

Though American statesmen are unwilling to play a part, other great figures like Henderson of England, and Briand of France take up the torch where we laid it down. It is no wonder that Henderson, in sheer desperation, points the accusing finger at America and says: "In these last few years we have begun to re-establish mutual understanding and for that reason we owe an undying debt of gratitude to the great leaders of the French and German people."

Economists, bankers, business men and the plain people of America, now groping in the darkness of pessimism, scanning the far-off European horizon, can find a gleam of hope in the proceedings at Geneva. Without an American leader in attendance, Briand, Henderson and their conferees are blazing the way through the wilderness. Sometimes I wonder how Woodrow Wilson, from the world in which he now lives, must look upon these present happenings in Europe, and what he thinks of the petty part the leaders

the Editor

THE AERIAL WAR GAMES.

Conditions Which Make Them Essential Should Not Exist.

To the Editor of The New York Times:

The manoeuvres of our air forces over various cities help us realize the stupendous preparations the nations are making in this ominous modern war weapon. While we have 672 war planes, Great Britain is reported to have 1,547 and France, 4,667. From the standpoint of achievements we can only admire the marvelous progress being made; but from the standpoint of actual warfare, these portentous developments must fill those who think with dread and horror.

For airplane warfare means gas attacks on great cities, accompanied with terrific conflagrations in strategic centres of manufacturing, communications and transportation. Each belligerent nation will seek at the earliest possible moment to paralyze and destroy the enemy's fighting power and to terrorize the civilian population, in its efforts to destroy their fighting morale.

Extended battle fronts of huge armies will avail nothing in defending the populations behind them.

Protection of civilian populations is acknowledged to be practically out of the question. "Providing gas masks for a whole population is manifestly impossible. Science can invent a new gas almost every day which will always be one step ahead of the best protective devices," declares Professor Haber, director of Germany's poison gas service during the war. The matured judgment of the International Red Cross Committee, given last October after prolonged study, is to the same effect. In modern warfare industrial establishments along with munitions and communications, have become as important as soldiers. Belligerents therefore will "strike behind the battle front and destroy those institutions on which the life of a civilized country depends—factories and mills, the telephone, telegraph, electric service and railroads. The field of battle would thus extend over the whole of the country at war. * * * War would be waged against all the civilian population: women, children and the aged would be exposed to the combined attacks of gas, explosives and incendiary devices, for all these weapons could be used simultaneously."

Our air armada has made vivid to us all the overwhelming disaster to a city of a really formidable airplane attack.

It would seem unbelievable, were it not a fact, that the United States has refused to join with other nations in agreements not to use poison gas for purposes of war. One of the treaties resulting from the Washington Naval Conference in 1921-22 did indeed forbid the use of poison gas, and the United States Senate

MILLIKAN DISCERNS SCIENCE-RULED ERA

Einstein's Collaborator Says Revised Conception of Deity Faces Brutal Facts.

DEFENDS HUMANISTIC VIEW

Holds No Scientist Can Achieve Goal Without It, in Address Before Phi Beta Kappa.

Science has led to a radical change in man's outlook toward religion and a "capricious and omnipotent god" has been replaced by the modern conception of a deity "who rules by law and is more dependable than the god of other days," Dr. Robert A. Millikan, scientist and winner of the Nobel Prize in 1923 for his work in physics, declared last night in an address before the Phi Beta Kappa alumni at the Savoy-Plaza. Dr. Millikan's subject was "Science and Humanism."

Dr. Millikan, who is a director of the California Institute of Technology, is leaving here Friday on his way to California, where he will work with Dr. Einstein during the Winter on problems of physics, he said.

The development of what he described as "the scientific method" has caused a "stupendous" change of outlook toward the supernatural, Dr. Millikan asserted. He defined the scientific method as consisting, in a general way, of the application of the experimental method before "the tribunal of brutal facts, without regard for the bearing to authority, previous philosophies or human desires." Observation and experiment are the keynotes of the scientific method, he declared, explaining that in his opinion all of the basis of human knowledge must rest on these foundations.

Lays Human Progress to Science.

Dr. Millikan said the view of God held by former generations conceived of man as at the mercy of the supreme being, and even as "a plaything of God." That view now has been discarded and, thanks to science, mankind has gained a measure of control of nature and environment, he asserted.

"The scientific method of doing and believing things distinguishes our modern civilization from previous eras," Dr. Millikan said. "The real development of the human race to its present high level may be said to have begun with the origin of the scientific method."

Although the scientific manner has been applied to a "tremendous" extent already, its even wider application to the problems of life is necessary and desirable, the scientist declared.

"Science is the leader in the amazing changes which have taken place and are taking place right now in human civilization and human thought," he added. "The twentieth century is essentially a scientific world. Science is the mainspring of our age.

"As the world progresses it will become more and more scientific. This is an era of specialization. But the world ahead of us is a world of even greater specialization along scientific lines, for we must have a higher degree of specialization for solving man's problems."

For Science-Humanism Marriage.

Dr. Millikan decried the opinion that science and humanism "live on separate planes." This idea is baseless, he said, "for science owes its origin to humanism and science and humanism must be linked together in our thinking." Any individual who does not realize that science is not a bar to humanism is essentially "a narrow, one-sided sort of person," he said.

Declaring that humanism makes for a breadth of interest without which no scientist and no other human being can "achieve the utmost goal of living," Dr. Millikan made a plea to his audience "to bring about a definite and inseparable marriage between science and humanism."

The proposal was received with enthusiasm by the audience of about 300 men, all members of the honor society and most of them occupying positions of prominence in the intellectual world. Charles E. Hughes Jr., president of the New York Chapter of Phi Beta Kappa alumni, who presided, declared that Dr. Millikan's proposal would be placed before all the chapters of the society throughout the country with the idea of organizing a national movement to win support for the scientist's project of a science-humanism "marriage."

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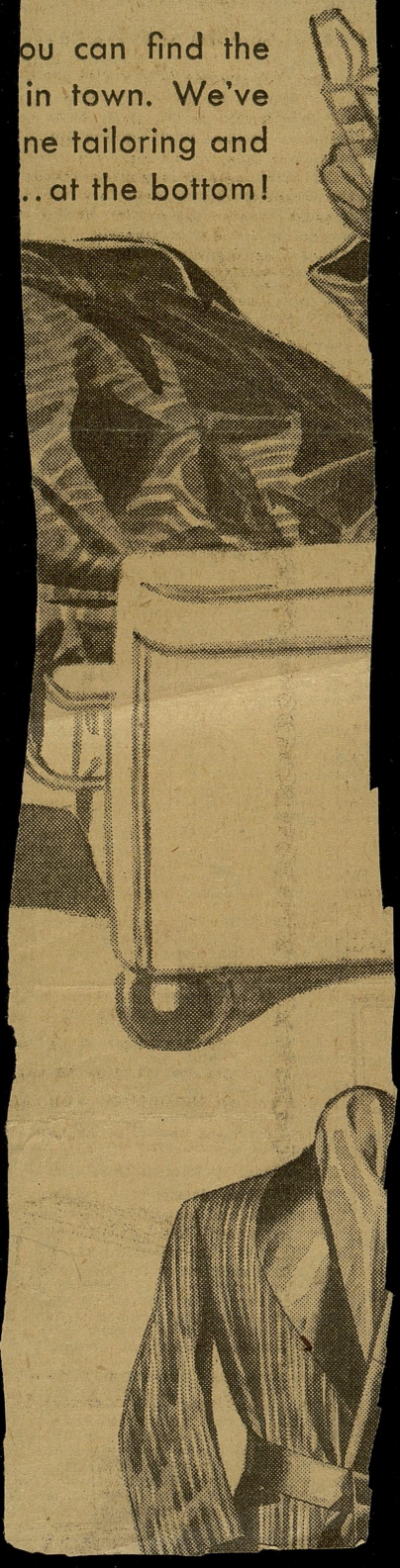


The New York Times Book Review

May 7, 1950 SECTION 7

MILLIKAN: MAN OF SCIENCE AND OF GOD

The Story of How His Work Helped To Shape the Thinking of Our World

THE AUTOBIOGRAPHY OF ROBERT A. MILLIKAN. 311 pp. New York: Prentice-Hall. $4.50.

By ARTHUR H. COMPTON

IT would be difficult to find a person whose life is more representative of the course of modern history than is that of Robert A. Millikan, whose work in science has helped to change the world's thought, and whose contributions as a citizen have substantially strengthened our nation. The great event of modern history is the emergence of a democratic society in which life is vastly influenced by science. "I suspect," writes Millikan, "that the changes that have taken place during the last century in the average man's fundamental beliefs, in his philosophy, in his concept of religion, in his whole world outlook, are greater than the changes that occurred during the preceding four thousand years all put together." Why? "Because of science and its applications to human life, for these have bloomed in my time as no one in history had ever dreamed could be possible." Millikan's autobiography illustrates the growth of this scientific influence, in which the author himself had a powerful hand.

Science owes its origin to men from many nations. A remarkable aspect of its recent growth, however, has been the increasing importance of the part played by Americans. When Millikan began his study of physics in 1893, Europe had many great figures making notable contributions. American scientists were rare indeed. Toward the close of his career he finds his compatriots occupying a leading place. Noteworthy also is the fact that some 60 per cent of the present leading American scientists have originated in the Midwest, so that the author's birth and upbringing in the Mississippi Valley is representative of the majority group of American scientific men. Statistically typical of the training of our scientists are likewise the facts that he was the son of a Protestant minister whose six children later moved to various parts of the country, and that his initial education was in the public schools and in a denominational college.

THUS it is that Millikan's story gives an example of the characteristic contributions that America has made to the growth of modern thinking, and an understanding of some of the factors that have brought America into its present position as a world leader. One factor is that our men of action have been carrying on the pioneer tradition.

A Nobel Prize physicist (1927), *Dr. Compton, as head of this country's atomic metallurgical project during World War II, directed research leading to development of the atomic bomb. He is now Chancellor of Washington University, St. Louis.*

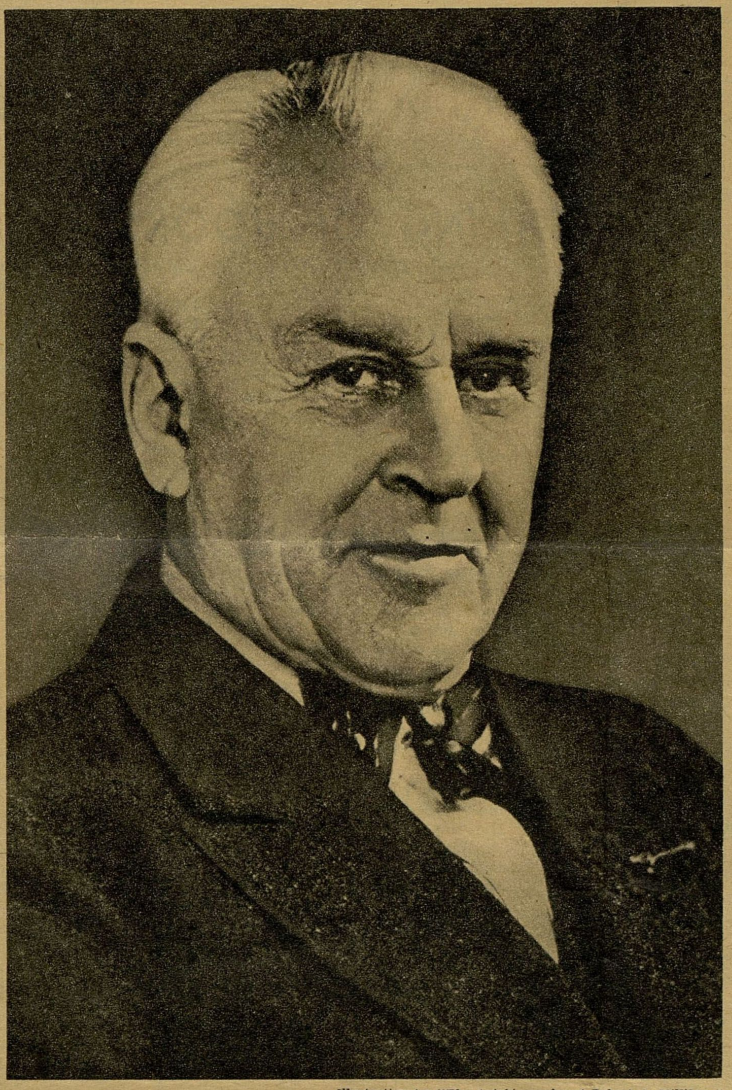


Illustration for "The Autobiography of Robert A. Millikan."
Dr. Robert A. Millikan.

To the pioneer the world was what he could make of it. He asked little help from outside, and he built for the future. During Millikan's boyhood the men who controlled the affairs of his community were themselves the pioneers. There was no other thought than that they could shape their world to their needs. This they were doing, and they expected the rising generation to carry on the program of making theirs a better world. Such was the author's heritage.

A corollary was devotion to duty, the prime virtue both of the pioneer and of the American Protestant. A priceless example is afforded by Millikan's account of his wedding. I know personally something of his admiration and affection for his charming wife. Yet his description of his marriage is confined to the following statement: "On April 10, 1902, I married Greta Blanchard. I was just then getting my 'Mechanics, Molecular Physics and Heat' ready for the printer, and in order to finish it before going to Europe I read proof until 6 P. M. on my wedding day. I had a bad ten minutes when I found the exit door locked, but finally located a janitor and got out in time to appear at the Blanchard home to play the assigned role."

It is an expression of this devotion to duty and love for his science that the major part of Millikan's autobiography should be taken up with stories of the great events in which he participated. These events include the growth of physics from a dormant classical subject to a dynamic, growing field of research; the work of the American scientists as they took their effective place in the first World War; the establishment of the National Research Council and the development of the National Academy of Science into an effective agency for advising the Government; and the creation of the California Institute of Technology, which has brought new life to technical industry in California and has afforded to the nation a valuable pattern for engineering education.

OF especial interest to the scientific reader will be the author's account of his own remarkable researches. His proof that all electrons bear precisely the same electric charge and his accurate measurement of that charge is one of the classic experiments of modern physics. His precision measurement of the ratio of the energy of a photoelectron to the frequency of the light that ejects it, reinforced the evidence for Einstein's theory of the photo-electric effect, and was an important step in establishing the photon theory of the nature of light. His spectroscopic studies of high-voltage sparks in a vacuum not only extended greatly the experimental knowledge of spectra but also made possible a better understanding of the properties of highly ionized atoms.

He performed a great service to science in calling attention to the significance of cosmic rays, and with the help of his students, using them effectively for revealing new elemental components of matter. He tells of this work in his well-known manner, full of personal anecdote and rich with references to his conversations with the world's scientific leaders. Since the time of Benjamin Franklin, there have been few if any native-born Americans whose researches have affected more significantly the development of scientific thought.

Not the least of Millikan's contributions have been in the writing of scientific books. Written in cooperation with others, these have included college textbooks on physics, a translation of Drude's classic work on optics, a monograph on cosmic rays and a masterly discussion of the relation between science and religion. His writings that have perhaps had the greatest influence have been his "First Course in Physics," originally done in cooperation with Henry Gale, which during its successive editions has been studied by millions of stu- *(Continued on Page 33)*

Poets' Column

Incident in Silver

THE trees on the rim of the mountain
Stood stark in the lifting light
That spilled from the hidden fountain
Where the withered grass turned white;
Turned white and the sequins glistened
On the robe spread over the ground;
Something stirred and I listened,
Listened, and heard no sound.
Then the hour in the village struck
As I watched the full moon climb,
And I saw the head of a buck,
His antlers covered in rime.
The moon, the frost, and the deer
And I were caught in the spell
In the silver month of the year,
In the silver sound of a bell.
The clouds came over to staunch
The light that the moon had lost
And the buck with the silvery branch
Raced a shadow over the frost.

A. M. Sullivan in "Incident in Silver" (The Declan X. McMullen Company).

From "Winter Solstice"

NOTHING, nameless, nowhere, everywhere:
When you came to your cradle I was there.
Creaturely kind in lion and lamb,
In star shining, in bud breaking, I am.
I am fear and faith, the fall and the contrition,
The aching hope and the wry fruition,
The bread of communion, the wine of bliss,
The living water of quietness,
The corn ripening, the linnet calling,
The first feathers of dusk falling,
The comrade, the lover, the casual friend.
I am that you shall find at the day's end.

Gerald Bullett, in "Poems." (Cambridge University Press.)

Native to That Place

MEN who with wide and narrow eyes
investigate the huge and little
have not been able to devise
lenses to pierce to Paradise.
Apocalypse to any saint
is heaven frescoed in his skull
and the angelic brother's paint
on the cell wall at last grows faint.
Without a crown or telescope
the child who sings because he wakes
inhabits heaven past the hope
of Galileo or the Pope.

Dilys Bennett Laing, in "Walk Through Two Landscapes." (Twayne Publishers, Inc.)

"John hasn't been the same since his publisher decided to condense him."

SPEAKING OF BOOKS

SANTA FE, N. M.

By J. DONALD ADAMS

FOUR flags have flown over the Palace of the Governors in the old plaza of Santa Fe—Spain's, Mexico's, the Stars and Stripes, and briefly, for two weeks in 1862, the flag of the Confederacy. Although there are other American cities as old or older, in none other is the far past so pervasive or its presence so immediate. The reminders are everywhere and constant: in its ancient buildings, in the faces of its Indian and Spanish natives, in this valley through which Coronado passed four centuries ago. And now, thirty miles to the northwest, in Los Alamos, stands a cradle of the incalculable future.

There is, it seems to me, an arresting irony in that proximity; that here, where time has moved in such a slow stream, where so much has resisted its passage, there should have come into being this hatchery of science holding within it the promise either of man's doom or his great betterment. About fifty miles northeast of the Los Alamos atomic plant lies the pueblo of Taos, where life has followed an almost identical pattern for centuries—for just how many we cannot be sure.

THE junction of past and present has always proved stimulating to writers. The fact that the Southwest, especially Arizona and New Mexico, makes one conscious of time—not in the clock sense, but in somewhat the same way it is felt when we live beside the tides of the sea—accounts in some measure, I think, for the attraction it holds for the creative worker. Its wealth of material, its dramatic and colorful history, are only the outer wrappings of this attraction. Nor is it only because the Southwest deepens in us the sense of time, of the long perspective, that artists of one kind or another have found here food for the spirit. It is the kind of country which quickens man's curiosity about the important things, which carries his mind back to origins and causes, pricks him into speculation about the fundamentals of life and death.

It stimulates, too, his sense of wonder, that capacity which it is so important for the artist in whatever form to retain. Sophistication, which might almost be described as a numbing of the sense of wonder, always results eventually in a loss of depth, in a preoccupation, however cleverly expressed, with the surface of things; you can trace that development in the history of any literature. It is only natural that religion and art, stemming from the sense of wonder, should have so great a part in the life of the Indians.

FOR that sense is fed in so many ways by the character of the physical environment: by the hugeness of the land itself, with the Grand Canyon at the apex; by the extreme violence of its climatic disturbances; by the blazing depths of its night skies. This is the kind of land that cradled the great religions of the world, and out of which came the great poetry of the Hebrew prophets and psalmists. It will be surprising, I think, if it does not in time yield a literature of greater depth, perhaps, than any we have had.

What has been written so far—and a great deal has been written—has been for the most part, I think we might say, in preparation for that literature. The bibliography of the Southwest is already bewilderingly large, and I doubt whether that of any other region of the United States matches it in variety. Because it is a land that bears so deeply the imprint of the centuries, it has been the source of a growing body of scientific literature; the archaeologists, the geologists and the ethnologists have found it rewarding ground. Its history has been copiously but not fully written; much spade-work, I understand, remains to be done for the decades immediately preceding occupation of the region by the United States.

DURING recent decades there has been a great outpouring of descriptive writing about the region, much of it excellent. It has been more interpretive in character than most of our other regional writing of this kind, partly because of the three strata of population — Indian, Spanish and Anglo, as they say here. More than half the population of New Mexico today is Spanish-speaking, and I wonder how many people in other parts of the country know that New Mexico's Legislature is still bilingual—the only one on the Continent except for the Province of Quebec.

Everyone who comes to the Southwest goes away with the desire to know more about it, and as with any country that fires the imagination, the prospective visitor does well to prime himself beforehand with a few books that will heighten his response to what he sees. My own acquaintance with the literature of the region is sketchy enough, but there are a few books known to me which I know will be profitable for any readers of this column who may be coming out here for the first time.

Erna Fergusson's "Our Southwest" serves well as a general introduction to the whole region; both she and her brother Harvey Fergusson, whose "Rio Grande" is saturated with the feeling of the country, write as natives to the land; Haniel Long's "Pinon Country" is a sensitive and informing book about northern Arizona and New Mexico; Ruth Laughlin's "Caballeros" deals understandingly with the Spanish half of the population. And, of course, no one should set foot in Santa Fe without having read Willa Cather's "Death Comes for the Archbishop."

Treasure Chest

The Greek World

HOWEVER contracted the material horizon of the Greek world may have been, the corresponding expansion of the spiritual was even more marked. It is to the latter that we owe the profound influence exerted by the Greeks on all succeeding generations in the West; it is this that explains the profusion and the perfection of their creative works and those sharply defined qualities of heart and of mind which are associated with them everywhere and which place their works beyond reach of comparison with the works of any civilization before or after. It matters little whether one turns to their political and social advances or to their philosophy, literature and arts—for that matter, even to their crafts—the imprint of the spirit is invariably the same on one and all. It gives to arts and crafts, to literature and philosophy, and to the entire civilization as a whole, an unparalleled unity of structure and of design.

Arthur L. Whall, in the introduction to "The Greek Reader." (Duell, Sloan & Pearce.)

Serving Life

THE world we are born into is real because it is full of living things, and there is no other reason whatever for considering it real. And so each of us must choose between helping or not helping what lives, must make up his mind to serve life or to destroy it. A person who concludes that he cannot live for himself alone, will have a spiritual relation to the world and will prove his oneness with it. He will testify by what he is and does that spiritual life is inside natural life. He shows his willingness to share our common burden of suffering and thus he will come to understand that the stronger his reverence for natural life, the stronger it will be for spiritual life. The place in him where Heaven meets earth, will instruct him that one helps bring the Kingdom only by learning to be thoughtful in that human way which means to be concerned and responsible.

Haniel Long, in "A Letter to St. Augustine." (Duell, Sloan & Pearce.)

The Artist

FOR lack of a congenial society, the artist often lives in isolation, with an aloofness which is variously called: by society people pose and lack of breeding, by the authorities a dangerous attitude, by his neighbors madness, by his family egotism and pride.

Marcel Proust, in "The Maximes of Marcel Proust." (Columbia University Press.)

THE NEW YORK TIMES BOOK REVIEW—Volume LV—No. 19. May 7, 1950. PUBLISHED weekly by The New York Times Company, Times Square, New York 18. SUBSCRIPTION price: $3.00 per year; Canada $3.50; other foreign countries $4.00. ENTERED as second class matter January 11, 1921 at the Post Office at New York under act of March 3, 1879.

Millikan: Man of Science and of God

(Continued from Page 1)

dents, and his own "The Electron," which in later editions included also the other fields of experimental physics covered by his versatile research.

The latter volume became a handbook for those following similar lines of study. His colleagues have good-humoredly referred to it as "Happy Days and Nights in Millikan's Laboratory," thus indicating both the point of view from which he wrote and the fascinating story of intellectual adventure that he told. In the present volume he tells of the conditions under which these books were written, the urgent need for adequate texts and the importance of presenting in understandable perspective the work upon which he was engaged.

It is fortunate that the author has used his autobiography to express his mature thought on certain major issues, such as: the requirements for peace, the essentials of a good education, and the vital place of science and religion in life. Let him speak for himself:

> I said then (1914) as I say now, that if the democratic, peace-loving peoples who in the long climb upwards from savagery toward civilization have outgrown the ideology of conquest and are trying to replace it by rational procedures have not the intelligence to unite to defend themselves when they are attacked by the wild beasts of the jungle who propose to thwart that effort and to perpetuate the idea of war and conquest, then there is no hope for the future of mankind.

MILLIKAN does not anticipate important economic consequences of atomic energy, but he considers most significant its effect in deterring people from attempting to solve disputes by war:

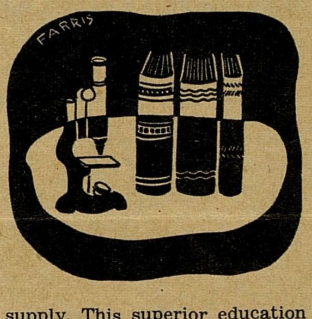
> The great service to mankind of the advent of the atomic bomb has been to make as clear as crystal, to all classes and conditions of men the world over, the necessity * * * to find a substitute for war in the handling of its international relation. * * * [This] in itself, without reference to further inventions of any kind, will make a new world; and its influence in making a new world will probably be greater than all other influences combined.

Millikan's view of education is that it "exists primarily to prepare men for actual jobs including that of effective living outside one's job." In sharing in the development of the California Institute of Technology, he had an opportunity to put this idea into practice. The result is an institution in which engineering students learn the scientific basis of technology, and at the same time participate in such cultural studies as English, history, economics, philosophy and ethics.

It is a matter of serious concern to Millikan that our nation's expenditure for alcoholic drinks is twice as great as the total cost of our public and private schools of all levels. The often expressed thought that more and better education for all of our citizens costs more than we can afford he considers preposterous, and a sad reflection on our sense of values.

WE can make our educational opportunities adequate to the demand, he believes, only if we will steer away from higher education those not fitted for intellectual pursuits, and give them advanced training of a manual and commercial type, accompanied by an understanding of the opportunities and privileges of free citizens. Thus we can meet the conditions required to build a great democracy.

I should add that the form of Millikan's own institute shows that he recognizes clearly the other essential aspect of education in a great democracy, namely that of making available for those destined to become the leaders of our thought the most adequate and stimulating education that we know how to



supply. This superior education cannot be given to many, for those competent to give it are necessarily few. Thus if such education is to be used to good effect, a wise and careful selection must be made of the students to whom it shall be offered. In our present educational pattern, this is perhaps the most important responsibility of private education and it is that toward which Millikan has directed his attention.

Perhaps, however, in no field are the author's comments of greater significance than in that of science and religion. He places "(1) the *spirit* of religion, (2) the *spirit* of science (or knowledge)" as the pillars upon which rest human well-being and all of human progress.

The contrast between this view, typical of a large group of American scientists, and that of the European positivists is striking. To the positivists, religion is a superstitious delusion that is the antithesis of science. To those represented by Millikan, religion and science form two distinct aspects of man's life, inspiration and knowledge, which while mutually related cannot be inconsistent.

FOR one with Millikan's background, the assumption that goals and ideals are significant is taken for granted, and the task of religion is to select these goals wisely and to make them effective in life. Science becomes useful in giving a reliable basis for one's choices, and for implementing one's purposes with the strength that comes with knowledge. Traditional religious doctrine is useful so far and only so far as it aids in understanding and cultivating the possibilities for good that lie in the human spirit. It is with this in mind that he quotes a statement in which he participated in 1923, and which was signed by forty-five leaders of religion, science and human affairs:

> The purpose of science is to develop, without prejudice or preconception of any kind, a knowledge of the facts, the laws, and the processes of nature. The even more important task of religion, on the other hand, is to develop the consciences, the ideals, and the aspirations of mankind.

THIS latter sentence would in fact seem to constitute the author's definition of religion, that which is concerned with "the consciences, the ideals and the aspirations of mankind." When this meaning is grasped, the great importance that he places upon religion becomes evident. The common essential of all good religion he selects as "the attitude of altruistic idealism." "It is so to shape my own conduct at times as, *in my own carefully considered judgment,* to promote best the well-being of mankind as a whole."

"Never in history," he writes, "has mankind faced a situation which forced every person on earth to ask himself so insistently the question, 'How can I help to make a better world?'" Here is evidently the key to the remarkable ardor, diligence and persistence with which Robert Millikan has worked and lived for the eighty years of which he writes. He has had a burning passion to help make a better world. He has thus carried on in the spirit of the pioneer community into which he was born. With regard to physical powers he has indeed helped men to improve their lot. If they will also catch his vision of a more worthy life toward which they can work, they will have progressed also in well-being.

FOR those who would understand the scientists that have played so large a part in changing our world, I do not know where to find a more illuminating book than this. It is authoritative and eminently readable. It includes valuable source material regarding not only the history of modern science but also the great events of the last half century as recorded by a keen reliable observer. Only in certain matters of minor significance, such as his pessimistic view of the future possibilities of atomic power, would the reviewer consider the thoughts expressed by the author as misleading. Taken as a whole, this autobiography is an important contribution to the understanding of what is perhaps the greatest age of history. I expect it to be read for many years to come.

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