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SCIENCE VERSUS LIFE[1]

By Dr. A. J. CARLSON

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I AM grateful for the honor and conscious of the responsibility of speaking to you on this occasion. Many of you are probably disappointed that my theme is not one in which I may claim special experience and competence. But I felt that this is not the time and place to display one's personal wares, the special minutiae of our common endeavor. I have chosen the harder way of thinking aloud, perhaps neither wisely nor well, on a problem of deep concern to all scientists and all other citizens. In so doing it may be that the apparent urgency of the problem obscured the factor of personal incompetence. But I assure you that this eclipse is not total. Should I bore my seniors, seniors in experience, wisdom and years, may I suggest that perchance there is a precipitate, even from folly; and should I exasperate our "young men in a hurry," may I remind them that the general education of the scientist-citizen is incomplete, even at the age of threescore and ten.

When the hurricane strikes ships at sea, frail hulls founder, while the crew of sturdier crafts experience anxiety, if not panic, and are for a time deflected from their course by the temporary violence of wind and waves. But they ultimately make their goal, thanks to human courage, the compass and the fixed stars. Such hurricanes, man made, have struck human society, and its institutions, from time to time throughout recorded history. We call them war. The world is now in the midst of one such period of violence, labeled "the worst"; because human memory is short, and even yesterday's experience is less vivid than that of to-day.

[1] Annual lecture under the auspices of Sigma Xi and in cooperation with the American Association for the Advancement of Science, Philadelphia, December 30, 1940.

There is anxiety and fear, if not panic on board. When storm clouds cover the heavens men of little understanding question the compass of science, fear that the stars of rectitude will guide no more, and with scant hope drift with the violent wind. The compass of science is not only questioned, but it is charged that this very compass has led us into the hurricane, that science is in conflict with society. So I propose to address myself to these questions: Is our age led or dominated by science? Is science in conflict with the best interest of society? Is it science and the scientific method that lead nations into war? Only last year a British scholar said: "In Europe to-day it is rather dangerous to ask questions, it is much safer to discuss how a question should be asked." To-day this danger is by no means confined to Europe. But as I read the human record in mud, and rocks, and ancient ruins, on tablets of clay, in scratches on stones, papyrus and paper, I think I discern evidence of *the ascent of man,* through asking all kinds of questions at all times, and seeking the answers by the best methods of the age. If *we* do less, we admit that science and civilization is a blind alley in human evolution.

Is ours the Age of Science? Or rather, in what sense is ours the Age of Science? An eminent physicist recently said, in this very city (Philadelphia): "In no previous time in human history has life and thinking been so greatly influenced by science as it is to-day." This is undoubtedly true, but does that alone make ours the Age of Science? I think not. Those who, accusingly or proudly, describe our times as the Age of Science usually cite as evidence the modern aspects of man's inhumanity to man or the numerous practical applications of the discoveries in physics, chemsitry, geology, biology and medicine during the last hundred years, such as the steam and gas engines, the telegraph, the telephone, the airplane, the radio, modern surgery, fair control of infectious disease, modern sanitation and many other inventions and measures that contribute to the convenience, the efficiency, the health, the comfort and the happiness of modern life. It is true that science has, during the last hundred years, increased enormously our understanding of the nature of the world and the nature of man, and with that greater understanding has come greater control of the forces that act in man and in his environment. But fundamental discoveries in science are the achievement of but a few people. The practical inventions based on these discoveries are also the work of a few men, relatively speaking. And the physical and chemical inventions are mostly gadgets that merely modify our tempo and external mode of living. I contend, and I think I will be able to prove to you, that the great mass of the people of our age, the rank and file of men and women of our day, even in the most enlightened countries, in their thinking and in their motivation are nearly as untouched by the spirit of science and as innocent of the understanding of science as was the "Peking Man" of a million years ago. The modern man adjusts to an environment greatly modified by the scientific efforts of the few. The "Peking Man," we may assume, adjusted himself as best he could to nature in the raw. A span of about a million years separate the two. And yet the two are about equally innocent of science, in the sense of the spirit and the method of science as part of their way of life. For science is more than inventions, more than gadgets, however useful and important they be. Science is even more than the discovery of and correlation of new facts, new laws of nature. The greatest thing in science is the scientific method, controlled and rechecked observations and experiments, objectively recorded with absolute honesty and without fear or favor. Science in this sense has as yet scarcely touched the common man or his leaders. The character of human society in any age is determined by man's thinking, motivation and behavior rather than by external gadgets. The erroneous assumption that ours is the Age of Science, or the very limited sense in which this is true, has led many people to charge to science some of the follies and failures, some of the violence, the brutalities, the suffering, the confusion throughout the world in recent years. Some of these people tell us that "science has failed," that we should declare "a moratorium on science." As if we now understood all things; as if real understanding is harmful; as if we should seal the book of scientific knowledge of to-day against the generation of to-morrow. People who talk thus, who advise thus can not understand either the spirit or the method of science. We can not afford to declare a moratorium on honesty, on integrity, on objectivity, on experimentation, for that would take us straight back to the jungle. The way of science is away from the jungle, away from its violence and fears. If the way of science at times, such as the present, seems obscure and even dangerous, that is due to too little, not too much understanding, of the nature of man and our universe, and to the further fact that we do not or are not permitted to follow the light of science we now possess.

If our age is "The Age of Science," our rulers, our legislators, our businessmen, our educators, our farmers, our factory workers should give evidence of comprehending, using and following the scientific method. In a recent volume the Dean of Canterbury says: "Our social and economic order is neither scientific nor Christian. When I read, as a headline in the *Observer* that Poland's good harvest was a *severe blow to recovery,* I recalled the words of an American professor of agriculture after seeing ten million acres of cotton ploughed under and five million pigs slaughtered: 'If this will bring national prosperity, then I have wasted

my life.' The thing is monstrous, an age when science is frustrated." In the broader field of human relations, what do we see on the horizon? Conspicuous, certainly, are these: greed, force, faith and war. These are certainly more conspicuous than the ways of reason based on scientific understanding. In the last analysis, *war is murder and stealing on the part of somebody.* War is the extension of the practices of the jungle into modern life. The technique of modern warfare is modified by scientific discoveries, but the elements that make for war are certainly not scientific. Hence the persistence of war can not be laid at the door of science. It is due rather to the failure of science and conscience to as yet essentially modify human conduct. For we must assume that sooner or later reason based on understanding will modify human behavior. Even animals with no cerebrum can be conditioned. But, lest we go too far in this optimistic dogmatism, let us also remember that while we have "tamed" the dog, we have not yet "tamed" the tiger.

The scientific method demands that we suspend judgment until we know the facts. It demands honesty, integrity and industry in ascertaining the facts. *The scientific method and dishonesty are incompatible.* But scientists are but human beings, and they frequently make mistakes both in facts and their interpretations. Now, *is our age conspicuous for honesty and integrity?* Is there less lying and deceit locally, nationally, internationally, to-day than yesterday? The answer is all about us. Modern propaganda, and a good deal in modern advertising, have the earmarks of lying as a fine art, rather than the character of honesty, objectivity, truthfulness and accuracy of science. It is, biologically, evident that we will have to live with greed for some time to come. But the more serious question is: *Can human society survive without individual, social and national guile?* If the answer is "No," we probably have here the most fundamental conflict between the scientific method and society.

Science, in spirit and method, knows no political aspects or national boundaries. Individuals of all races and nations have contributed to our present understanding of the nature of man and of the world. There is no Democratic logic, Republican mathematics, Nazi physics, Fascist chemistry or Marxian biology. The spirit and the method of science can not change with capitalism or socialism. This appears to me axiomatic. But fanaticism in society and governments can temporarily retard discovery and further advance in the understanding and control of life and nature. And yet we hear claims from the Germany of to-day of a special Teutonic or Nazi physics, claims from Russia of something called Marxian genetics, whatever that is. These stupidities characterize our age, but they are not the characteristics of science. If the science of modern biology has made out anything with a high degree of certainty, it is the fact of the essential unity of our present human race, and that such differences as the skin color, hair color, speech, size of body, etc., are not in any way fundamental. And yet notions of racial superiority and inferiority are widespread—as if the differences in skin color, size of lip or length of nose had any significance when it comes to the capacity of the brain or the control of the emotions. An able American anthropologist wrote last month: "There are no measurable physical or social qualities which are in any given group (of people) superior or inferior." There are, of course, great differences in the kind and quantity of education and in the mechanical appliances due to science among the different peoples of the earth.

If even our so-called educated fellow citizens were scientific their conduct would be more influenced by proven facts than by wishful thinking. At the recent Century of Progress Exposition in Chicago, the Adler Planetarium had a record attendance. So had the shops of the astrologers and fortune tellers on and near the exposition ground. If there is anything that has been proved to the hilt in biology and medicine during the last hundred years, it is the effectiveness of vaccination against smallpox. There are no ifs and ands about it. It is one hundred per cent. effective, and practically one hundred per cent. safe. Of course, wherever human hands, human agencies, are involved accidents will happen sometimes. We can't do much, at present, to prevent colds, pneumonia, cancer, diabetes or too high blood pressure, but we can prevent the deaths and the disabilities from smallpox by protective vaccination in early infancy. And in most cases the immunity thus conferred lasts throughout life. Despite all these facts, men and women in this and other civilized countries neglect and oppose vaccination against smallpox. We have large groups of people organized into "anti-vaccination societies." And these are not all ignorant people. Some are college graduates. If these people walked in the way of science, they would accept and be guided by proven facts.

The exact biologic relations of man to other animals are still, in part, a matter of theory. Animal evolution is usually slow. Most of what we see of it to-day took place in the past. We can only dimly observe the past; we can not experiment with it. Animal evolution is probably now going on, but so slowly that we usually fail to discern it. But the essential identity of the structure and function of tissues and organs in man and animals is not a theory. It is a proven fact. The heart, the liver, the stomach, the lungs, the blood, the eyes, the ears and even the brain are made up of the same stuff, and subjected to much the same diseases, wear and tear and aging in man and animals. It is also true that practically 90 per cent. of the under-

standing gained in the last hundred years of preserving health and controlling disease has been secured through experiments on animals. And yet people, even in civilized countries, oppose experiments on animals as futile and cruel, as of no benefit to man. These people are not all ignorant. But they surely are not scientific. They do not accept, they are not guided by proven facts. Their thinking and motivation have not been touched by the spirit and the method of science. Moreover, the majority of people in some of our states, through their legislatures, pass "anti-evolution" laws, as if the course of events of the past could be altered by legislative dicta of to-day. The legislatures of Tennessee, Ohio or Kansas might pass laws against floods, drought, dust storms, grasshoppers and similar catastrophes, but that would be as futile as it is unscientific.

It is still a common practice of man, so-called civilized man, to follow *post-hoc* reasoning; that is, because one event may sometimes follow another, the two events are therefore necessarily causally related. Mankind as a whole, and even leaders in business, industry and government, do not yet thoroughly understand or follow the *principle of control, the principle of experiment. Post-hoc* reasoning is one of the commonest sins against the scientific method, and we still see it occasionally in those who should have been trained in science; for example, modern physicians. As an example of *post-hoc* reasoning in medicine, I can cite the case of a physician who had practised medicine honestly in a far western state for forty years. A number of years ago, he told me in all seriousness that he had discovered a specific remedy for influenza. I was naturally curious, because influenza is one of the maladies which has so far largely defied modern scientific control. On being asked what his remedy was, he replied, "Good whiskey and plenty of it." The doctor was apparently perfectly sincere about it. When I asked him how many influenza patients he had treated without whiskey and how many of these recovered, he looked at me in surprise and said: "You understand, I have treated every one of my influenza patients with whiskey during the last forty years, and I have had a high percentage of recovery." This physician, though stupid, was too honest and venerable to poke fun at. I was tempted to ask him how many recoveries from influenza he thought he would have had if he had had them read Mary Baker Eddy's "Science and Health" at an angle of 45 degrees, practised Couéism, or had their spines or toes twisted according to the chiropractor's cult. Another example is that of another honest physician in a southern state using a remedy whose virtue, if any, was essentially 20 per cent. alcohol, a so-called female tonic, a Southern counterpart of Lydia Pinkham's well-known vegetable compound. The case was that of a young girl working twelve hours a day in a factory in a Southern city at low pay. She lived in a garret room, with poor food and poor sanitation. She had a high degree of anemia. The doctor wrote: "I took this girl out of the factory, sent her to the country for three months with relatives and gave her this female tonic. After three months she had nearly recovered from her anemia, thanks to this tonic." It is not surprising that even physicians fall into this error of reasoning, because in the not distant past medical education was only partly scientific and physicians are only human.

To what extent or in what sense is science in conflict with society? I think there is much confusion, misunderstanding and unwarranted generalizations on this point. Not so many years ago the American Association for the Advancement of Science declared, by resolution: "Science is wholly independent of national boundaries, and races, and creeds and can flourish only where there is peace and intellectual freedom." This position is clearly in conflict with the cyclical psychosis exhibited by *homo sapiens,* in mass, throughout the ages. But whether there is a conflict of science with the primary interest and ultimate well-being of society is at least an open question. Only last year an outstanding physicist declared: "Science makes man human." I presume our colleague meant that science tends, or should tend, to make man more human. The possible conflict between science and society in this statement obviously depends on our conception of what are the desirable human qualities, or behaviors, to-day and to-morrow. If these are deceit, violence and war, there is conflict between science and society, for deceit, violence and war are the very antithesis of the scientific method. Two years ago a colleague uttered the following dictum: "Here on this continent where science has achieved its greatest application, science is in conflict with society. Science and technology have gone so far that the present social structure is facing its debacle. Nowhere else in the world to-day is science in such militant conflict with the social structure under which science survives." The same author also speaks of the "prostitution of science for war." We have here, clearly, a confusion of science and the scientific method with the uses, largely by a non-scientific society, of the understandings and the gadgets developed by the methods and the applications of science, for satisfaction of the ancient human drives of greed, hate and vanity. The modern use of scientific gadgets and forces for violence and war is not essentially different from the ancient use of the hand, the teeth, the rock, the stick and the club in similar drives by our primitive ancestors.

Recently the President of the United States addressed a letter to the president of the Massachusetts Institute of Technology, calling upon the engineering profession to "cooperate in designing accommodating

mechanisms to absorb the shocks of the impact of science on society." It seems to me that here, again, we have a confusion of the scientific method and science with technology, and an identification of science in general with the scientific achievements in chemistry and physics. Is it not the technology developed through the latter achievements with which our President is concerned? Evidently the President, though he said so, did not really mean science in general or the scientific method, for if our fellow citizens really are shocked by new data, new generalizations, new uses and controls of matter and energy, new understandings of man and the universe brought forth by science, what kind of shock absorber would he suggest against such new knowledge, and would he not agree that those who are shocked by new understandings should be so shocked? For instance, what kind of shock absorber for society may we look for in the matter of the biologic and medical sciences and the services of modern medicine, especially in prevention and control of infections and the application of modern knowledge of nutrition? To be sure, society once appeared to be shocked by the theory of the evolution of life, and the growing evidences of the unity of all life. These facts do disturb some people, but in my judgment that disturbance is wholesome for society. However, the science of modern biology and medicine certainly helps to preserve and to prolong the life of the ablest as well as the least fit members of society, least fit physically and mentally. Biology and medicine have also greatly increased the average life span, so that to-day society has a greater percentage of members past fifty, sixty and seventy years. To be sure, modern warfare tends effectively to counteract this "impact" of science on society. And it is not yet clear that the lengthening of the life span, particularly the effective life span, is an undesirable "impact." In brief, the alleged conflict between science and society is based largely on misunderstanding and on unwarranted generalizations.

The services of science to society are, primarily, increased knowledge and understanding. That such increased knowledge, understanding and control of the forces of nature are used, not by scientists, but by society, with increasing effectiveness in the continuous and recurrent drives to satisfy greed, lust, hate and vanity, will, in my judgment, ultimately prove to be due, not to the inherent nature of the scientific method or of knowledge *per se,* but to the failure of man, so far, to be effectively conditioned by science and the scientific method.

It is sometimes asserted that science is amoral if not immoral. The latter may be true, if it is immoral to challenge and destroy taboos and traditions based on ignorance and misunderstanding. But to call the impartial, industrious and earnest search for new knowledge amoral or immoral conflicts with my conception of immorality. As I understand it, there is no conflict between the scientific method and our sense of justice, though I admit that the latter stems from a much broader base than science. Individual scientists may at times, in their ivory towers, express distrust of society or the common man, as disclosed by the following recent statement from an eminent surgeon: "Whether the public interest (in medical research) is something deeper than curiosity, and whether it can be relied on as a potent factor for the common good have not been demonstrated. Indeed, a study of the historical background of surgery invokes in the mind of the medical scientist a distrust of the public." The doctor cites among other examples the Edict of Tours (1165) declaring surgery not respectable. But that edict was not the work of the common man. It was a product of the leaders of the church.

On the other hand, the defeatists among us, noting the conspicuous though superficial rôle of science in modern thought and modern life, occasionally see in science and the scientific method the very root of some of our modern ills. Thus the leaders of a little college on our Atlantic seaboard have boldly undertaken to rectify a conspicuous educational failure of Harvard University by providing "conditions for liberalizing and humanizing science." And this the college hopes to achieve by the "strategy of taking specialists in the sciences and re-educating them in the liberal arts." We are not told what to do for or do with the people who were educated in the liberal arts before they became specialists in science. Maybe these unfortunates are acephalic satraps of Satan or just dead and do not know it. A pessimistic colleague in the social sciences recently referred to our times as one of "intellectual chaos and moral confusion which has undermined the confidence of men. It has become so common to justify the bad and belittle the good, that the words good and bad, honor and dishonor, truth and falsehood have lost most of their meaning for persons who influence public opinion." Even if this pean of pessimism is entirely true, what evidence have we that it was better instead of worse yesterday, a hundred, a thousand, a hundred thousand years ago, when science and the scientific method were unknown? Few if any real scientists will take exception to the humanist who insists that "under the shelter of the word culture there must be room for a more dynamic ingredient added by the person who can produce fine things." I think among the "persons who can produce fine things" are the men of science, and among "the fine things" are new facts about men in health and in disease, new facts about the universe, new facts about the nature of life and matter, new understanding and new powers of control of the forces of nature.

Many world events in recent years have made some

assert that worthwhile human society can not persist or prevail without the perennial supremacy of deceit and greed, violence and war. Others question whether these very antitheses of the scientific method can persist side by side with science and the necessary human qualities that go with the method of science. Deceit, violence and war have certainly been with us before the dawn of history as a part of the "struggle for existence," while science and the scientific method are of a much more recent vintage. It is also true that the "struggle for existence" in smaller groups such as the family, the tribe, and the nation ultimately curbed, at least in part, both deceit and greed, violence and war. Can such curbing be achieved on a larger scale or is it desirable that such curbing of man's past drives be achieved in the interest of the future welfare and progress of man? So far as I can see there is only one answer to this question, and that answer is given both by history and by the primary interest of society. To refer again to the resolution of the American Association for the Advancement of Science: "Science can flourish only where there is peace and intellectual freedom." Are intellectual freedom and peace the desiderata for man? If this is so, there is no fundamental conflict between science and society, as I view society of the future. But some of us are inclined to take the more virile position of the immortal Pasteur who said: "Science and peace will triumph over ignorance and war." But to-day the "blackouts" imposed by our modern barbarism seem particularly monstrous, partly because of the current bright light of scientific understanding. The endemic and cyclical psychosis of our race is nothing new. There were shackles, even more deadly, on the human mind in other ages. There were burning libraries and rivers of human blood in other days and climes. But through the past and present immense and ugly wilderness of man's inhumanity to man there runs a trail, at times scarcely discernible, but still a trail, blazed by the search for understanding, occasional kindness and the groping for justice.

The evident failure of modern science to measurably influence human drives and conduct, individually, nationally, internationally, are probably to be sought in three factors: (1) the character of our prevailing education. Our prevailing education, starting in the home and in the church, in the grade school and the high school, and extending into the college, is largely *education by dictation.* It is indoctrination rather than education by understanding the why and wherefore through experimentation and controlled observation. This applies to countries other than our own. There are those in our own country who insist all along the line on education by more and more dictation and indoctrination. Merely the memory of and the ability to repeat a heterogeneous number of facts, or even coordinated facts discovered and interpreted by science, is not education in the method of science. We can teach a parrot to talk Latin and repeat a syllogism, but that Latin-speaking bird is still a parrot. In the bulletin of the Association of American Colleges for December, 1935, there is an article entitled, "The Alumni Go to College." In this article are brief accounts of faculty offerings to the alumni of their respective schools. Science is not even a "second best," an "also ran." But Princeton offered its alumni "Modern Problems in Sea Power." Wooster University offered "Suggestions for Travel in England." Mount Holyoke reported on "We Americans of To-day" and "The Church in the Nazi State." At Rollins they took "An Excursion into the Field of Biology," which might mean anything, and in 1933 Lawrence College had something on "The Subterranean World," which may have been either geology or politics. The University of Akron listed as important food for alumni thought: "The New Deal and Foreign Trade." Barnard College evidently considered it most important for its alumnae to learn "How to See a Play," and also to learn something about "The Modern Dance Movements," and in 1935 Lawrence College presented its alumni "Gothic Architecture" and "The Artistic Prospect of the Cinema in America." Evidently these topics interest and entertain our alumni. They remind us of a recent paper on education, entitled, "Learning and Lollipops." But do we have to follow Hollywood? Are we sure that our alumni can not digest stronger meat? If they can not, there is little of worthwhile significance in our A.B. and B.S. degrees. It is interesting to travel in England; but to us it is more important to live the full life in America. The latter demands something more than "Modern Dance Movements" and the "Arstistic Prospect of the Cinema." It demands the latest news on heredity, on the electron and the proton, on bacteria and health, on soil conservation, chemistry and cancer; on birth control and pest control; on better foods, better homes, better children; and on a thousand other problems of life on which science has provided understanding and working out our control.

(2) Considerable responsibility for the failure of science to essentially modify human conduct must be laid to the scientists themselves. Many of us are scientists only during our working hours, and fall into the common errors of the average man when we step outside our own specific field. Many of us have considerable fog in our brains and clay in our feet, and this is discerned by leaders in other human endeavors and by the man in the street. Scientists frequently become dogmatic both inside and outside of their own fields. A few years ago a British biologist of some standing published a little book ("Heredity and the Ascent of Man") in which he tells us that: *"Perhaps*

the most serious obstacle in the way of any permanent intellectual improvement in the human race is the democratic nature of the governments which make the laws and rule the affairs of the more civilized states. . . . Recent events in Italy and Germany, where democracy has been replaced by dictatorship show the practical possibilities of state action for race improvements." As if anything could possibly be proved in the way of elevating German and Italian character and intellect in the short period that these dictators have held sway. For the progress of science the very antithesis of dictation and regimentation seems the most favorable environment. But it appears that even the most thorough conditioning in the natural sciences does not always carry over into the problems of social, economic and political relations. A few years ago an American zoologist wrote a book with the title "Out of the Night," a queer book from the pen of a man of science, in which he tells us that: *"In the capitalistic state the search for truth will eventually languish of its own internal debility."* The title of this book is "Out of the Night." It should have been "Into the Fog." For is it not fact that the individual search for truth is an internal drive, to be sure, influenced by the political, social and economic environments, but, at least in part, independent of them? The dawn of science antedates capitalism. Science has been fostered, at least by individual capitalists, and the record of dictators in the matter of fostering the scientific way of life is, to say the least, as varied and uncertain as that of capitalists. There is an embryonic dictator beneath the skull cap of every man. And the fury against individual freedom, science and honest inquiry is not confined to any race, creed, clime, economic or political order.

(3) The third factor is the tremendous resistance of man to new ways of thinking and new ways of life. During the past million years that man has evolved under the influence of the non-scientific or raw environment, he has developed emotions and habits and drives that are not easily, speedily or permanently modified by the environments and techniques developed by man himself through science. There is no use crying over this situation. It is one of the recognized scientific facts, and we must accordingly work toward the goal with longer vision and greater tolerance and patience. Science as an educational and social force is but of yesterday. Man has been exposed for ages to the fundamental ethics of the great religions, using the elements of fear, punishment and perpetual reward as motives, something that science can not do. And yet the effects of this exposure seem neither significant nor lasting.

From all the evidence now available it seems clear that in the past greed, guile and violence had survival value for primitive man. Assuming that these drives can be curbed on a national or international scale by new *mores* based on understanding, reason and emerging justice, will the latter have equal survival value in and for the kind of society we hope to build? My answer is yes, with this proviso: I think we must apply new and different measures to reduce the number of the least fit. We have enough information to make a beginning in that direction now, but prevalent mores prevent it. Unless reason based on understanding effectively guides social evolution of to-morrow in the direction of elimination or reduction in number of the least fit, those who can not or will not strive for the individual and the common good, I see no escape from the degeneration that invariably follows biologic parasitism, except the ancient law of tooth and claw.

Now, I shall try to say in one minute what I probably failed to make clear in fifty. As I see it, ours is not an age of science. Men are still driven by greed and confused by guile, rather than guided by reason based on our expanding knowledge. Science has greatly enlarged man's understanding, conquered many of his diseases, lengthened his life, multiplied his joys, decreased his fears, and added much to his physical comforts and powers. But man may and does use these and other achievements for a greater social injury, instead of for a further social advance. Science is specifically human, in that it stems from the innate curiosity of all men, and the conspicuously plastic brains of the ablest, if not the noblest, of our fellows. If this be so, it follows that the scientific method and its products can not be, in any fundamental and permanent sense, in conflict with human nature, though our present human society, a product of the past, dominated by greed, force and fear, may be and is in conflict with the scientific method. Whether science and the scientific method, whether understanding, honesty, reason and justice can contrive survival values equal, if not superior to the blind forces of nature which shaped man's past, is as yet in the laps of the gods. Still, we can not deny the possibility, and we will nurse the hope that the hairy ape who somehow lost his tail, grew a brain worth having, built speech and song out of a hiss and a roar, and stepped out of the cave to explore and master the universe, may some day conquer his own irrational and myopic behavior towards his kin.

I think we can say, even in the face of current pessimism, that during the ups and downs of a million years man has gradually acquired more understanding, more freedom from fear, more dignity, greater kindness and a clearer conception of justice. Even though for the moment, "the bird of sorrow" is not only flying over our heads, but is actually nesting in our hair—to borrow a Chinese proverb—that bird will not nest in our hair forever, even though a blackout on the light of science is decreed in every land. For, slowly but

surely, the method of science will help to make life more intelligent, toil more cheerful, fear and hatred, pain and tears less prevalent in our lives. If in any place or time the blind fury of hatred of our brethren and the insane violence of war render the pursuit of science impossible, and the scientific method submerged and forgotten, it will be rediscovered, in better days, by better men.

CONTRIBUTIONS TO SCIENCE BY THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY[1]

By Dr. KARL T. COMPTON

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ON this program in celebration of the fortieth anniversary of the Research Laboratory of the General Electric Company, I am privileged to represent the thousands of scientists in every field of research whose work has been significantly aided by the generous cooperation of the members of the staff of this laboratory, and who have been stimulated by the fundamental scientific discoveries that have come out of it in continuous succession. A typical example, of hundreds of similar situations, was my first contact with this laboratory just thirty years ago.

As a graduate student in Princeton University I was working under O. W. Richardson, the distinguished British physicist who first understood the true nature of thermionic emission—the emission of electrons from hot metals which is the basic performance of filaments in radio tubes and x-ray tubes. Richardson's experiments had led him to conclude that this emission was really an evaporation of electrons out of the hot metal, but another school of thought held that the phenomenon was due to chemical action on the filament by residual gases in the enclosing evacuated tube.

At that time Richardson visited the laboratory in Schenectady. He learned from Langmuir that what scientists had theretofore called "high vacua" were really very crude vacua indeed, and that by prolonged heating of the glass tube nearly to its melting point and by even more vigorous heating of the metallic electrodes contained within it, the amount of residual gas could be reduced a thousand-fold below the amounts in the best vacua hitherto realized by scientists. This new high vacuum art having been disclosed to Richardson, he was able to return to Princeton and prove by conclusive experiments the fallacy of the chemical theory of thermionic emission.

At the same time Langmuir, who had even then been pioneering in the properties of surfaces, showed that thermionic properties which Richardson had thought characteristic of tungsten were really due to layers of thorium, not over one atom thick, which formed on the tungsten surface by diffusion of this impurity to the surface of the hot tungsten filament and which for many purposes greatly improved its ability to emit electrons.

This incident recalls a whole group of scientific investigations and their practical applications which have been main lines of continuous study in this laboratory. Coolidge's discovery of a way to make ductile tungsten, and hence tungsten filaments, revolutionized the incandescent lamp industry. It, and the high vacuum studies, led to the Coolidge x-ray tube now in practically universal use. These, with Langmuir's work on surfaces and diffusion, led to improved radio tubes and hydrogen arc welding. Langmuir's studies of surfaces have contributed much to our knowledge of chemical reactions and are now opening up new vistas for the physiologist in his study of biological actions at membranes and cell boundaries in living organisms. As by-products of the x-ray, and to a considerable extent through the work of Hull in this laboratory, has come our modern knowledge of the arrangement of atoms in crystals. Using thermionic emission as a tool and making new applications of the kinetic theory of gases, Langmuir and Tonks have made the most notable contributions of the past twenty years to our knowledge of the complex, but highly interesting, important, and often spectacular, phenomena of ionization and electrical conduction through gases. By his scholarly exposition of such diverse subjects as magnetism, quantum theory and atomic structure, and by his able direction of research efforts, Saul Dushman has been a worthy collaborator in this highly individualized but well coordinated group.

If time permitted I should like to mention other scientific achievements of this laboratory, and other able contributors to its program, for they are many. I have only mentioned a few of the high spots by way of suggestion of the scientific work which has gone forward in what the public has come to think of as the "House of Magic"; but whose "magic" is in reality the logical outcome of systematic, orderly hard

[1] Fortieth anniversary celebration of the Research Laboratory of the General Electric Company, Schenectady, December 17, 1940.