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THE ADVANCEMENT OF SCIENCE[1]

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IN the evolution of science there have been changing environments which have profoundly influenced the progress of science. The general cultural background of a period, the printing press, the founding of the famous scientific academies in the latter part of the seventeenth century and early in the eighteenth century, politics, philosophical doctrines, geographical exploration, religion, superstition, etc., which, throughout the period of which we have any knowledge, have hastened or hindered the advancement of science. The church has played its part in creating an environment in which science struggled for freedom, though it was not antagonistic to science which conformed to its teachings. The Mosaic account of Creation and of the Flood, the belief in a geocentric universe with a heaven and a hell close at hand, for example, delayed the progress of geology and astronomy. Science has gradually but relentlessly broken down some of these barriers. Copernicus exploded the belief in a geocentric universe; geologists brought evidence to bear on the age of the earth; Darwin taught us to think in terms of evolution; Pasteur dispelled the darkness and ignorance concerning disease, and Fraser suggested we should reconsider our ideas about many of our beliefs and to look for their origin in the beliefs held by primitive peoples.

Not only have philosophic and scientific thought at various times created an environment which influenced the advancement of science, but mechanical aids to sci-

[1] Concluding part of address of the president of the South African Association for the Advancement of Science, June 29, 1942.

ence have also profoundly influenced the environment in which scientific advance became possible. The microscope, from the simple beginnings of Robert Hooke and van Leeuwenhoek in the seventeenth century, has played an important role, not only in biology, but also in geology and in metallurgical research. Astronomy could not have advanced without the aid of the telescope, the spectroscope and the pendulum clock. The photographic plate has been an invaluable aid to science, especially to astronomy, and recently the film has come to the aid of science in the study of the structure and behavior of micro-organisms. It should not be forgotten that underlying all the numerous mechanical aids to science, are scientific principles discovered by men of science and which have been applied and developed over a long period.

When we regard science as an indivisible whole and trace its development, we become more impressed than ever with the influence of changing environments at different periods on the advancement of science. When we look back on the gradual advancement of science from its early beginnings to our times, we must admit that a spirit has been created that should act as a beacon to a better world if men would be guided by the teachings of science. As in organic evolution, mutations may suddenly arise in science and may persist or die in a longer or shorter period depending on a favorable or unfavorable environment resulting from fresh knowledge. When Newton and Leibnitz about the same time, and probably independently, discovered the fundamental principles of the calculus it can be regarded as a mutation—something that suddenly appeared and incidentally persisted as one of the most powerful tools ever given to mathematicians. A complete break between organic and inorganic chemistry—another example of mutation—happened in the year 1828 when Wöhler prepared urea from ammonium cyanate. Avogadro's hypothesis that equal volumes of gases at the same temperature and pressure contain the same number of molecules is another example of a mutation that was able to persist in the environment of the Laws of Constant Proportions, Multiple Proportions and Reciprocal Proportions. The demonstration by Galileo that the acceleration of falling bodies is the same, irrespective of their mass, was a new mutation that appeared in the evolution of science and which has persisted. Ptolemy's views about a fixed earth round which the sun and stars revolved could perhaps be cited as a mutation that persisted until it died in the new knowledge acquired in the sixteenth century. Another example might be Stahl's phlogiston theory of combustion, which could not survive in the environment created by Priestley and Lavoisier. But science does not generally evolve in this manner, but from small continuous variations that may or may not persist. A study of the development of ideas concerning the cell and organic evolution and the conception of the atom, for example, will provide numerous illustrations of small or larger variations that have persisted or died in the environment in which they appeared. The evolution of science also provides many examples of a struggle for existence in adverse environments. The veneration of the views and opinions of the Greeks, *e.g.,* Aristotle and Galen; the spirit of superstition that existed for centuries; the attitude of the church; all provided an unfavorable environment in which science struggled for existence. The fundamental truths of science, while their rapid development was retarded, persisted even under such adverse conditions and flourished and spread.

If you accept my thesis that the origin of science lies in the pre-history period of man and that its advancement is a product of the human intellect, you must also concede that the stage modern science has reached is the greatest triumph of the human mind. I have often asked myself the question whether the development of science has anything to teach us. I personally think it has. I can never believe that man, notwithstanding the terrible mess he has made of his social and economic problems, has not the brain capacity eventually to solve them. Science has taught us that, when dealing with scientific problems, the subject must be approached with an unbiased mind willing to be led wherever truth leads and not to be influenced by preconceived ideas or prejudices. The history of science provides us with many examples of theories and beliefs being discarded when fresh facts were brought to light. The world of science is quite unperturbed at such occurrences and accepts them as the price to be paid for a more complete understanding of nature, rejoicing that a step nearer the truth has been attained. Science as such will not solve all our present-day social and economic problems, but I am certain that they can be solved if minds trained in scientific methods are brought to bear upon them. When men are prepared to expend the same energy in applying scientific knowledge to large human problems, as they expend on physical inventions, on industry and on commerce, many such problems will be within sight of solution. The intellectual world must have been shocked when Copernicus, on observed facts, stated that the earth moves round the sun and not the sun round the earth; the world was shocked when Darwin stated that the facts of nature did not support the belief in a special creation. Is there any reason why the world of vested interests, the world of greed, the world of selfishness, should not be shocked out of their complacency by the searchlight of scientific methods of inquiry? We *know* that the

social and economic conditions under which the majority of men live could materially be improved—no proof is needed—they are plain for every thinking man to observe; yet a state of affairs is allowed to continue in our social and economic systems that would not be tolerated for a moment, had they been problems in a matter of pure science. Science can assist to alleviate, and science has assisted in alleviating, the conditions under which human beings live. It remains for the statesman, the administrator, the politician to bring to bear the scientific outlook on the problems we are still faced with. We see in the history of science how opposition to new thought has again and again been overcome. History also provides us with examples such as the opposition to general education, the opposition of vested interests to the abolition of slavery, but both were eventually broken.

The whole organic world, the universe, our thought, beliefs, customs, etc., have all undergone a process of slow evolution. In many ways man has consciously assisted evolution in desirable directions in the social and economic spheres. The process has been slow, but with the will and the right spirit it can be still further speeded up. There are dangers to be faced, as for example a government forcing a system on the people that may destroy some of their inherent rights as individuals. The average man has not lost imagination nor is he usually a person without a sense of good-will towards his fellows; by mutual trust and cooperation many reforms could spring from below upwards and not be forced from above on the people.

An American sociologist wrote that one of the most terrible examples of unscientific mindedness is an eminent physical or biological scientist speaking on social matters. As I only lay claim to having some little knowledge of biology, I shall *not* fall into the error of making dogmatic statements, though I consider the awakening interest of scientific workers in social problems which science has created, is a healthy sign of our age. I do, however, make a plea that some of our urgent social problems such as adequate food and housing, the opportunities for the enjoyment of physical fitness and health, be investigated by minds trained in the methods of scientific approach—a method that has solved many problems in the sphere of natural phenomena. One of the methods by which this may be attained is by some modification to our educational system, whereby young people may be trained, as part of their general education, in the appreciation of science and the scientific method by teachers fully competent to undertake such training. Unfortunately science is not always presented as something living but, as a well-known novelist put it, is presented "as a corpse which bit by bit we painfully dissect." Intellectual docility is often evidenced in our educational system. More importance is attached to the acquisition of correct beliefs than to the methods by which such beliefs are formed—authority instead of doubt is stressed. A knowledge of the history of science and of thought generally would stress that the doubting spirit of man has been the chief spur to the advancement of science and to human progress.

In another organization with which I have had the honor of being associated for many years, I have consistently advocated the policy of attracting young men of ability to its councils. The young man with intelligence approaches many problems unhindered by tradition or conservatism, while the older men of experience, if their minds have not atrophied so that they are unreceptive to new ideas, may act as a steadying influence. I consider that in all spheres of consultation on scientific matters the younger men of promise should be represented on the consultative bodies and their opinions given careful consideration.

It may savor of over-optimism for a generation that has lived through two terrible wars still to believe that the world can be spared such tragedies and that human beings may live full and useful lives untroubled by the specter of want in a world of plenty. But I am an optimist. I can not regard the triumphs of the human mind, as evidenced in one sphere, *viz.*, the advancement of science, as being without some significance and hope. This more especially when we know that civilization has existed for only an infinitesimal fraction of the period since man first appeared upon the earth. Some twentieth century philosophers, as illustrated by Bertrand Russell, are not so optimistic. He writes "the whole temple of man's achievements must inevitably be buried beneath the debris of a universe in ruins—all those things, if not quite beyond dispute, are yet so nearly certain that no philosophy which rejects them can hope to stand."

Even if we accept this doctrine, I think there is still ample time for man to readjust his affairs, so that like the repentant sinner he may meet his ultimate fate without fear.

In conclusion, I end up on a note typifying the outlook and spirit of science—a verse dedicated to Leonhard Stejneger, the American biologist, on the occasion of his ninetieth birthday:

The sons of science walk in endless line bearing the torch;
a few falter and drop,
But the rest close in: they who have a sign
Far on ahead that reads "You must not stop!"
Their quests are strange and wonderful—to bring
The stars to earth, to take the earth to sky;
To know the *what* of every living thing of all times past,
and then the *how* and *why*.