

3. THE RELATION OF PURE AND APPLIED PHYSICS.

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Pure science is an absolute prerequisite to the development of applied science. Both pure and applied science contribute directly to the progress of knowledge. Applied science has also an indirect influence on the progress of knowledge which is much more important than its direct influence. The very nature of our practical affairs, as well as our success in dealing with them, depends upon the state of our knowledge. Hence these four, pure science, applied science, the progress of knowledge and our practical affairs form a continuous line of related matters in which each is dependent upon all of those which precede it.

New discoveries in science, or more accurate determinations of known laws, are an absolute prerequisite to continued progress in applied science. If all discoveries in science should stop at the present moment, that is if all progress in pure science ceased, the progress in applied science would continue for a time at a decreasing rate, until the present acquisitions of pure science had been largely turned to the use of a man. The progress in applied science would then practically stop until new lines of application were opened by developments in pure

science. I make no attempt to estimate the time required to reach this state of stagnation in applied science. It is certain that the stagnation would come under the stated conditions. It is relatively unimportant how soon it would come. The important point to be kept in mind is that progress in pure science is absolutely necessary in the long run to progress in applied science.

It is this which makes it fundamentally important to encourage and to foster pure research in science in all feasible ways, by establishing well equipped laboratories, by organizations for research, by generous rewards to those who are successful in research, by every possible device to enable the exceptional man with unusual gifts in this line to devote his whole time in a favorable environment to pure research. An abundant harvest can not be gathered in applied science unless plenty of good seed is secured from pure science.

Although history shows that each discovery in pure science is ordinarily followed sooner or later by corresponding advances in applied science, yet it also shows that the lag which occurs between the discovery and its useful application, though sometimes short, is frequently very long. Applied science should be encouraged and fostered in order to shorten the lag. The application is as important to man as the discovery. Much less of genius is needed to make the application than to make the discovery. The rewards are also more obvious and more certain. On the other hand, the total amount of work awaiting the laborers in the field of application is very large and the total lag of application behind discovery is great. The harvest being gathered in applied science is much smaller than the possible maximum from the seed already furnished in pure science.

It seems to me that universities are responsible in part for the unnecessarily great lag of application behind discovery in science. The atmosphere of universities leads one to put strong emphasis on knowing and very light emphasis on doing, leads one to be rightly and fully appreciative of discovery, but to appreciate in a half-hearted way only the effective application of discovered truth. It tends to lead one to accord enthusiastic

praise to a Faraday, the discoverer, but to be mild and cynical in appreciation of a Westinghouse who makes applications of great value to man.

The history of any well developed branch of applied science furnishes illustrations of the relation which has been stated between pure and applied science, and of the variable lag of application behind discovery. A catalogue of the ways in which applied science touches and influences our practical affairs would be very long and would be a recital of ideas familiar to this audience. Most articles of food and all articles of clothing have been either improved in quality or reduced in labor cost by the accomplishments of science, and the same is true of practically every artificial object within your present range of vision. The stories of the railway, the steamship, the printing press, the telegraph, and the telephone have many times been told.

To stop here in our thinking, to stop with the contemplation of the accomplishments of science as seen in material forms, is to miss the most important features of the relation of science to the progress of knowledge, and to our practical affairs. The material accomplishments of science, engines, dynamos, machines, processes of manufacture, etc., are but the foundation of its influence in the world. The two hundred thousand miles of railway in the United States are much less important than the strong influence of these railways upon the spread of knowledge, the condition of the race, the development of character. Let us look beyond the mere material accomplishments of science to its all pervading influence upon civilization. Within the allotted time it is possible to indicate this influence in a sketchy way only, by a touch here and a touch there.

The locomotive, the marine engine, the printing press, and the telegraph have made all the peoples of the world acquainted and changed them from enemies into friends. The people of the United States and the Japanese, living on opposite sides of the world, are better acquainted and therefore more friendly today than were the French and the Prussians one hundred years ago, living as close neighbors. If two hundred thousand

miles of railway had existed in the United States from 1800 to 1860, the people of the North and of the South would necessarily have been so well acquainted with each other that the Civil War could not have occurred. All agencies which make different peoples understand each other tend to abolish war, for wars are based primarily upon the failure of nations to understand each other. Science by furnishing quick and cheap transportation has caused man to develop the travel habit, by putting printed matter within the reach of every one has made reading a habit of the masses, and by furnishing quick convenient means of communication, the mail and the telegraph, has produced the habit of keeping in touch with all the world. Thus science, by promoting mutual understanding between nations, has been the greatest of peace makers.

Science has also been very powerful as a peacemaker by producing such powerful weapons and such efficient means of concentrating quickly vast numbers of troops and their supplies that war is now so costly and so deadly that we can not afford to indulge in it.

In improving personal morals, as well as national morals, and thereby advancing civilization, the workers in applied science are extremely powerful. They build a smooth steel road and a one-hundred ton locomotive which draws a massive train at a mile a minute. Then it is found that the safety, the lives, of the hundreds of passengers on the train depend upon the quick and certain action of the man in the cab of the locomotive. He must not only see the faint danger signal within a few seconds, every time it appears before him, he must also act promptly and with good judgment, or pay the forfeit with his own life and possibly the lives of many others. This and other situations created by science, in which certainty and quickness of action of the nerves and brain are absolutely necessary, because great responsibility is concentrated in one man have been most powerful influences in changing this from an irresponsible, drunken world into a responsible temperate one. Contrast the sober alert locomotive driver of today with the drunken and relatively dull stage driver whom he superseded.

This was formerly a world in which the winner was the man with the brute strength and physical bravery which gave him the power to win in a hand to hand battle. It was a world in which all, even the fighters who secured the spoils and the kings who ruled the fighters, lived in comparative discomfort. It was a world in which the higher thoughts, aspirations, and the impulse to render unselfish service, which are the essence of civilization, came to but very few. The masses of humanity were too heavily loaded with hard labor, with real oppression from the classes above them, and with the effects of ignorance and superstition, to have a part in the crude civilization which existed. It was a world in which men knew only their nearest neighbors, in which nations perpetually fought against each other, in which each people was densely ignorant of every other and correspondingly suspicious.

The workers in pure and applied science, by bringing into general use a method of thought which is the antithesis of superstition, by providing efficient means of intercommunication and for the general diffusion of knowledge, and by turning the forces of nature to the uses of man, have changed this into a world in which the winner is the man who thinks clearly, controls himself, and may be depended upon, the man who serves rather than the man who fights. It is now a world in which millions live in greater comfort and security than did even the kings of the ages before the scientist. It is now a world in which the average man works such short hours and under such comfortable conditions that he has abundant opportunities within his reach to share in the real benefits of civilization, to develop himself to his full capacity.

Possibly it may seem that I have exaggerated the influence of science upon the progress of knowledge and its influence in changing the very nature of practical affairs. In terse statements there is apt to be some exaggeration. But I challenge a critical examination of the thesis which has been put forward that the progress of civilization in the past century has been founded upon science and would have been impossible without science.