from the ages shall be passed on with a still brighter flame. Let us champion the cause of education, in the best sense of the word, as having regard to its spiritual as well as its scientific side. Let us go forward with our own tasks, unflinchingly seeking for the truth, confident that, in the eternal dispensation, each successive generation of seekers may approach nearer to the goal.

Magna est veritas, et prœvalebit.

Arthur Evans

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THE IMPORTANCE OF SCIENTIFIC RESEARCH TO THE INDUSTRIES

America is in the throes of preparedness and many are the remedies offered for quick deliverance. These remedies are of two varieties, namely, genuine and quack; and at times it may be difficult to dissociate one from the other.

Schemes of all kinds are offered purporting to be of immediate and direct value in the program of national defense, but when sifted to the bottom are found to be, either wholly valueless, or detrimental to the cause. On the other hand, the national awakening to the necessity of providing adequate defense has been productive of measures and plans which, if carried through, would result in permanent assets to the country.

The conclusion seems to be warranted, that the major efforts in our preparedness program should be directed toward the improvement of industrial conditions. In the final analysis, war is a contest between the industries of the belligerents. Therefore, a country whose resources are exploited, whose industries and commerce are well developed, and whose systems of business, education and research have reached a high plane of efficiency would be incalculably better off in the case of a long exhausting war than if reliance had been placed on the military equipment alone.

Preparedness means, not only the optimum military and naval forces for repelling the initial onslaughts of the enemy, but also the power to quickly adapt one's self to the changing conditions brought about by war and to render available the latent resources in the shortest period of time.

It is the organization and development of these latent resources that should demand our attention at this time, as much as the preparation of war equipment for immediate use. This form of preparedness can not lead to militarism, for the results attained will be of as much value in time of peace as in time of war. Militarism is the great danger confronting our democracy at the present time, and war is its inevitable result.

To war the course of empire takes its way and the route is: *scaredness—preparedness—assuredness—war,* but a word to the wise is sufficient.

As a nation we are not sufficiently appreciative of the value to industry of research in pure science. In order to credit certain experimentation, we must see a well-established connection between the work in hand and the end sought. A clear and definite series of results pointing toward a certain conclusion must be produced before we are in a mood to consider the possible importance of the investigation.

Few of our manufacturers have realized the significance of a well-equipped research department in connection with their industries. This statement, however, does not apply to the testing laboratory, whose value has long been recognized and has its place in the factory. The expenditure of a certain percentage of the profits for launching investigations into unexplored fields is another matter.

Some of our manufacturers are still con-

tent to make their products like their grandfathers used to make them, as long as the industries pay a reasonable margin of profit.

The story is told of a large paint manufacturing company, where the superintendent had made repeated but unavailing recommendations to the board of directors for the establishment of a research laboratory in connection with the business. They could see no immediate returns accruing from such an expenditure, but finally yielded to the wishes of the superintendent and voted that a research chemist be employed not to exceed $75.00 per month, and that he be instructed to report to the head paint-mixer.

This attitude on the part of manufacturers has undergone a marked change and they are becoming more and more appreciative of the value in dollars and cents of scientific research. Whatever else may be the results of the European war, one thing is certain, and that is the inevitable stimulus to research in the industries. The influence that this division of science is having upon the progress of the war is exemplified on every hand.

A profounder testimony would be difficult to find than where the integrity of the Teutonic powers has been maintained for two years against a world at arms by the utilization of the results of one man's researches on the fixation of atmospheric nitrogen. Numerous other elements have, of course, contributed, but if nitric acid could not have been obtained in such enormous quantities, the war would probably have been at an end long before this. The latest developments of the Haber process will probably not be known outside of Germany until after the war, and it seems to me that this is one of the more important fields for research in this country at the present time. Why spend millions of dollars upon plants designed to employ an antiquated process, when it is known that other countries are now using a more efficient one? The temper of the American people is such that millions can be had for defense along known lines, but only a meager sum for research.

Almost every industry presents well-nigh infinite possibilities for improvement. The *ne plus ultra* of to-day will be scrapped to-morrow. What is required is an enterprising leader who dares to venture out into the woods on either side of the beaten path of factory routine.

The force of this statement becomes apparent the moment we awake from our lethargic sleep and begin to look about us. We find that the leaders in the industries are those who maintain research departments, for in that way they are able to keep ahead of their competitors by either supplying superior articles at equal cost or as good articles at less cost. Germany's dominating world industry in dye products has been built upon chemical research, its scientific instrument industry upon physical research. The perfume, drug and wine industries of France have been founded upon years of painstaking research.

Our own world industries of manufactured articles, such as photographic goods, oil and packing house products, machinery, steel products, electrical appliances, etc., all take root in research departments, and it is no chance coincidence that the industries supporting the most extensive research departments are those in the highest stages of development.

Now it is financially impossible for the vast majority of our industries to maintain research departments. They are as incapable of aiding their industries in this way as the individual farmers of the country would be in acquiring single handed the latest developments in agriculture as

worked out in the various agricultural experiment stations. Efficiency points to centralization and coordination.

The government has stepped in and aided the farmer where he was unable to get the results alone, but the government has not yet deemed it prudent to intervene in behalf of the small manufacturing industries so as to improve their products and put them on a higher plane of efficiency. This could be done by the establishment of a large government institution for chemical and physical research, with departments at least as numerous as the different industries to be aided.

Instead of the industries being helped by the government, they are actually hindered to a certain extent, especially in so far as unsatisfactory patent laws act prejudically against them. The vast majority of researches carried out in the universities are of such a nature that they have no bearing whatever upon present-day industries, and the essential results obtained in private research laboratories are kept secret so that the small manufacturer will ultimately be forced to the wall, unless he can surreptitiously acquire the processes of his wealthier rival.

Discovery is the aim of research even as it is the aim of all forms of experimentation. Discovery and invention may result upon the most superficial tests which in no sense could be classed as research. In fact, many important and far-reaching discoveries have been made as results of the crudest form of experimentation, but these are the singular exceptions. The rule is, that any important scientific or industrial advance has been made at the expense of years of experimentation and research along that line, coupled with the knowledge derived from countless other lines of work. One industry dovetails into another like the walls of a house and one science blends into another so that it is no longer possible to draw the dividing line.

Even as the sciences are developed by the contributions of thousands of workers, so each industry must depend for its advancement upon the labors and researches of a large number. What an enormous amount of research along many lines must have been carried out to bring the photographic industry to its present high plane of perfection! From the time that Scheele, Niépce and Daguerre made systematic studies of the actinic properties of silver salts, there has been an uninterrupted search for the hidden treasures in this field. The researches have extended into actinometry, organic and inorganic chemistry, colloid chemistry, electro chemistry, radioactivity, gelatine, glass, optics, heat, metal plating, mechanics, etc. No man is the discoverer or inventor of modern photography.

The men who do the pioneer work are usually railed at by the populace as impractical dreamers and scarcely ever live to see the full fruition of their labors. If Daguerre could have had a vision of the tremendous industry that has been reared upon the meager results of his research or if Clerk Maxwell and Hertz could have realized that their theoretical deductions furnished the basis for wireless correspondence across oceans, they could have met the attacks of their critics with a complacent smile. As an example of one man's contribution to industry, Pasteur is perhaps the most illustrious.

His thoroughgoing researches discovered the cause and pointed out the remedy for the souring and spoiling of beer, wine and fruit juices, and thus benefited France and other countries to the extent of millions of dollars. He also saved the French silk industry from certain destruction by the pébrine disease of the silkworm. He dis-

covered the cause and cure for rabies and anthrax, but greatest of all established the germ theory of disease and laid the foundation for serum therapy, an incalculable contribution to humanity. In commemoration of this notable work, his disciples will drink pasteurized milk for generations to come. Pasteur had his critics, too, even as formidable ones as the great German chemist Liebig who once wrote:

> As to the opinion which explains putrefaction of animal substances by the presence of microscopic germs, it may be compared to that of a child who would explain the rapidity of the Rhine current by attributing it to the violent movement of the numerous mill wheels of Mayence.

When the criticisms of thoroughgoing research come from the outside, they are not serious and vital, for time and subsequent work will establish the facts, but when criticisms come from the inside, from untrained officials in charge of the work, then it is they become serious.

What a mass of promising research work has been ruthlessly beheaded by conscientious superintendents, and directors in the name of "practical" results!

How can we distinguish between practical and theoretical research? What appears to the superintendent as being of no value whatever may have the germ of enormous practical returns in it, while the "practical" work he decides upon has such an immediate and superficial character that no appreciable gain, either for science or for the industry, will be made. This question of "practical research" is vital to the welfare of the American industries and should be given thoughtful consideration.

Neither science nor industry can make material advance until the basic laws and fundamental principles governing the same are understood, and the prime object of scientific research is to discover and verify these basic laws, while the purpose of a testing laboratory is to apply the laws already known to definite projects and industries.

What meager advance our electro-chemical industries could have made if it had not been for the discovery of the underlying principles by Faraday, Van't Hoff and Arrhenius.

Modern explosives owe their terribleness to the work of Sobrero, Pelouze, Eder, Schischkoff and Nobel. The soap industry is largely indebted to the painstaking researches of Chevreul; and the dye industry to Perkin, Hoffman, Fischer, Louth and Beyer.

Radium therapy was made possible by the discoveries of Mme. Curie and the multifarious applications of the X-ray rest upon the work of Crooks and Röntgen. The theoretical researches of De Vries and Pfeffer were of inestimable value to Burbank's plant-breeding experiments. Likewise, the "impractical" discoveries of certain rare gases in the atmosphere by Lord Rayleigh and Sir William Ramsay have now been made use of in the manufacture of the most powerful and economical incandescent lamps.

In this day and age no sane person would dare to say that a certain piece of fundamental research will be of no practical value for a hundred years to come. In a few years it might mean the cornerstone of an industry or a science.

At this time and in this connection, it might be well for us to ponder the words of the great French chemist, Dumas, when, in a speech delivered immediately after the close of the Franco-Prussian war, he said:

> The future belongs to science; woe to the nations who close their eyes to this fact. Let us call to our aid on this neutral and pacific ground of natural philosophy, where defeats cost neither blood nor tears, those hearts which are moved by their country's grandeur; it is by the exaltation of science that France will recover her prestige.

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