SCIENCE

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The Importance of Scientific Research in the Postwar Era[1]

George R. Harrison
Massachusetts Institute of Technology

THIS IS AN ESPECIALLY GOOD TIME to discuss the relation of research to postwar industry and agriculture, for not only has the postwar era arrived with a bang, but there has been a major change in the whole relation of science to the social structure within the past eighty days. I am therefore especially pleased to come at this time to Birmingham, where so promising a start has been made by the Southern Research Institute.

I need not tell this audience that the prosperity of the South depends on expansion of southern industry. Everyone present is aware that scientific research furnishes one of the most effective ways of promoting agriculture and industry. It is easy to quote exact figures in almost any industry one may choose to show how research has made possible a better product at a cheaper price, thus increasing sales and boosting both profit and wages. Department of Commerce figures show that, in 1926, two hundred thousand mechanical refrigerators were sold at $400 apiece. As a result of research and the increased know-how which resulted, a much better refrigerator could be sold ten years later for $160, or less than half as much, so two million, or ten times as many, were sold. In the radio field similar figures can be quoted. In 1926 one and three-quarters million radio sets were sold at an average price of $114. Ten years later, sets which were far better cost an average of $54.50, or less than half as much, and eight and a half million, or nearly five times as many, were sold. You may say that much of this improvement can be credited to the development of improved methods of production, but no one will deny that the most direct way to develop such improved methods is to study them systematically—in other words, carry on research.

In citing specific examples of effects of research on industry, I shall steer clear of selecting those dealing with our own Southland, regarding which you are so much better informed than I. Instead, for cotton I shall substitute wool and refer to a land much farther South and about 180° West. If you think your area needs industrial expansion, take a trip to the Antipodes, where nearly half the people in a continent larger than the United States live in three great cities hundreds of miles apart. The transportation system connecting Brisbane, Sydney, and Melbourne in Australia until recently consisted of slow-moving vessels plus a series of railways, much of whose rolling stock was discarded by the Long Island Railroad in 1905. I use Australia as an example, because its needs for research are similar to, but even more extreme than, those of the southeastern United States, and because the Australians have in recent years shown the same progressive spirit as yourselves and the same realization that scientific and technological research is the only answer to their most pressing problems. They are following this approach with the same vigor and success which mark your own efforts.

A year ago I spent several months in Australia. Like that of the South, her economy has been built up largely on primary rather than on secondary industries, and thus chiefly on wool, wheat, beef, and mutton. This is all very well in normal times, when an empire will take your wool, scour and weave it, and give back manufactured products in exchange. Most of the profits remain in the empire, however, and in an emergency weaknesses begin to show up. During the war there was a great shortage of lanolin for greasing rifles in Australia, although most of the world's lanolin originates there. In normal times wool was shipped from Australia to France, where the lanolin was removed and purified; then the wool went on to England for further processing, and some of the lanolin went back to Australia. When France fell, the lanolin industry disappeared, and Australians did not even know how to get lanolin out of their own wool.

Recent years brought a still worse bugaboo to terrify the wool grower (for "wool" read "cotton"). New textile materials were appearing from research labora-

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tories in other countries. Rayons and nylons entered the market, and rumors were heard of even more dangerous competitors of wool. The Australians did not take this sitting down. Their very effective Council for Scientific and Industrial Research put to work research scientists who soon discovered a new way of greatly reducing the shrinkage of wool by treating the fibers before the spinning process. They also set to work on the problem of making woolen strands distasteful to moth larvae and were having a fair degree of success at the time of my visit.

The Council for Scientific and Industrial Research has under its direction ten active research laboratories to serve seven million people. How many people are there in the southeastern United States?

I saw another example of Australian vigor in research in the optical industry. When the Japanese were coming over the Kokoda Trail in New Guinea and the people of Queensland had their automobiles loaded to move their families south at a moment's notice, the Australian optical industry consisted of a fine collection of sand banks. The Armed Forces needed optical instruments of the highest quality—roof prisms for range finders, for example, which had to be accurate in angle to within two seconds so that rays of light reflected by them would not deviate from their correct path by more than one foot in twenty miles. Ordinarily, these could be made satisfactorily only by the most skilled optical workers having years of experience. The Australians converted three academic laboratories into optical plants, made their own optical glass from local materials, and soon developed the needed skills for fashioning the most delicate optical parts. Two university physics departments had optical shops in quantity production when I was there, and astronomers in the Commonwealth Observatory, high up on Mount Stromlo, had taken their gaze from the stars and were working on tank telescopes. So successful were their efforts that they were shipping large quantities of roof prisms to the Frankford Arsenal in Pennsylvania. Now Australia has an optical industry.

Though there are said to be at least 2,264 industrial research laboratories in this country, too many corporations have set up what they call research laboratories, which are merely developmental and trouble-shooting laboratories. It is not easy for a board of directors to decide to invest funds, labor, and equipment when some direct, immediate return cannot be seen; yet that type of faith and imagination is what is required if the greatest financial return is to be realized. The greatest practical returns from research come when one is willing to cast his bread upon the waters and relax, as far as that particular bread is concerned, secure in the knowledge that eventually it will return manyfold.

The small industrial corporation cannot support a research laboratory of its own, yet it cannot afford to get along without research for improving its product and developing new products. It is to supply the need of such firms that such laboratories exist as those of the Southern Research Institute, the Mellon Institute, and the various university foundations, of which the Division of Industrial Cooperation, Massachusetts Institute of Technology, is typical. This is the first stage.

As a firm builds up its organization it ultimately reaches a point where it can support a research laboratory of its own. This is the second stage. But if any industry is satisfied to stop with even the second stage, its profits will remain at a level far below that which proper acumen makes possible. The needed third stage is that which may be called directed basic research, a typical example of which is given by the sugar industry. A large number of manufacturers of cane and beet sugar have banded together in the Sugar Foundation, which supports research on the chemistry of sugar in a large number of university laboratories. What is wanted is more information about sugar and what it is good for. When this information is obtained, the public will benefit in obvious ways, and the sugar industry will benefit from increased use of its product. Such broad-minded research is spreading as the benefits to those who support it become apparent and has already produced remarkable results in a large number of fields.

The fourth stage we may call "disinterested basic research." This is the most important of all, for without it the others soon lose sustenance. In years past it was difficult to convince a board of directors that they should make contributions which would enable a "dreamy" scientist to work in his laboratory at whatever he pleased. If they had not come to see that no apparently isolated fact is useless, and that the nonavailability of any particular bit of information may later make impossible the solution of a specific problem, American prosperity would be on a far lower level than it is.

Fundamental research usually could not in the past be undertaken with guaranteed immediate profit by any one company or even by one industry. It had to be supported by the whole economic community because it was of such broad scope. It was carried on chiefly in the research laboratories of universities and the great foundations. Thirty years might elapse between the discovery of the photoelectric effect, for example, and the development from it of an electric eye for television and talking motion pictures; or between the discovery of the electron and the development of

an electron tube for radio, or radar, or telephony, or a dozen other new industries. Yet this period is being shortened rapidly, for the more we know, the more we are able to find out, and the greater the number of pieces which have been fitted into the jig-saw puzzle of nature, the easier it is to fit in the remaining pieces, even though the area of the picture grows larger all the time.

Fundamental research is now, however, becoming a profitable undertaking for some of the larger corporations. The director of the Research Laboratory of the General Electric Company some years ago told me that he and his predecessors spent much of their time trying to get their research personnel back into the fundamental research which they had started thirty years ago. The original idea of their laboratory was the disinterested study of nature, because its director, Dr. Whitney, had the imagination to see that this was what would pay most in the long run. Over and over again, researchers in such laboratories as those of the General Electric Company and the Bell Telephone Company have been set to work in some field of fundamental research only to have one after another profit-bringing result intrude itself upon their notice.

I suppose that the reason digging for truth is not only more interesting, but more profitable, than digging for gold is that if urged on by the love of digging, one digs more deeply than if searching for some particular nugget. Practicality is likely to be short-sighted and looks so hard for some single objective that it may miss much that nature presents to one who is purposely digging for whatever may turn up.

When someone succeeds in inventing a gun which will shoot a bullet around a corner, it may become reasonable to expect to predict the outcome of any individual piece of research—that is, of real research as distinct from mere development. Progress in science is almost always made around corners instead of in straight lines. Most great discoveries have been made out of the corner of someone's eye. The most successful research laboratories are those in which funds are allotted to support research activities, a crew is set to work, and then everyone stops worrying about whether any particular job is going to pay back its cost in one year or ever.

The director of one of our most progressive research laboratories once told me with great pride that he had guessed wrong on nine out of ten of the greatest developments that had come from his laboratory. He was proud, not of the incorrectness of his guesses but of the fact that he never let them stand in the way of progress. When one of his young men came to him with a bright idea, he usually spent half an hour shooting it full of holes. Then, as the young fellow turned away, disappointed, he would say, "Go ahead and try it anyway. Work on this a bit and maybe you can prove me wrong." The young man worked, and although his original idea may have turned sour, something usually came of his research which led eventually to a new product, as likely as not to be more important than the one originally contemplated. You mak ask, "What is the function of a research director who is wrong nine times out of ten?" My friend said that his function is to listen to a man whenever he has an idea, give him credit when his ideas work, and see that he is kept cheerful so that his ideas continue to flow. As a result of this far-sighted policy, this corporation has ridden out all the ups and downs of economic storm, is almost without competition in its field, has stocks which are always considered to be a gilt-edged investment, and makes most of its profits from products which were not even thought of fifteen years ago.

Several years ago, Dr. Karl Compton told the National Association of Manufacturers that 2 per cent of the gross income of any industry could be expended effectively on research. Since then, this advice has been amply borne out, and the world has been plunged into a war in which the value of research has been demonstrated for all to see, as the strength of nations has been primarily their scientific and industrial strength. Britain was saved by the Royal Air Force, but it was only by a Royal Air Force implemented by the Radar that their scientists furnished in the nick of time. Since then, the Office of Scientific Research and Development under Dr. Vannevar Bush, skimming the cream of American scientific effort, has successfully aided our Armed Forces with a constantly increasing flow of new weapons and devices, which, taken in conjunction with those developed by the Services themselves, kept us abreast, and often ahead, of similar German advances. Those who expect great peacetime technological advances as a result of this extra wartime effort will not be disappointed, but it is still too early to discuss many of these advances in any specific way. One can only point to those industries involving air transport, electronic devices, food technology, and medicine as obvious examples of fields in which great strides are being made.

I should like nothing more than to be able to give you a list of new products of the next decade in the way of foolproof family airplanes; cheaply operated deep-freeze refrigerators; new types of cookery involving infrared rays and high-frequency radio waves; new runless, snagless super nylon fabrics; new medicines rendering atabrine, penicillin, and the sulfa drugs obsolete; new insecticides like DDT but selective so that, though they deal death to a mosquito or a

fly, they furnish nourishing vitamins to a honeybee; fluorescent lamps that burn softer and brighter than our present lamps; plastics that can be molded with a putty knife, only to set into hardness that cannot be dented with an ax; metals lighter than aluminum yet as strong and cheap per unit volume as steel; synthetic rubbers of a dozen kinds, so that while one gives a tire that will roll a hundred thousand miles, another makes tougher and thinner raincoats which do not run, stick, or offend the nostrils. I could go on endlessly with such a list, but you have all heard the predictions. The limitation on such prophecies is that the items we can foresee are only the minor ones; the unwritten part of the list will expand into a thousand additional devices which have not yet been thought of, but which the next generation will consider essentials of living. So, if you ask for a list of the better things which Americans can expect someday to have available, I refer you to a list of what Americans want. So great is my faith in the ability of the chemist ultimately to put atoms together into any kind of molecule that may be needed to produce any desired drug, plastic, textile fiber, vitamin, or rainbow-colored dye, and of the physicist to discover new kinds of X-rays to see through steel, new Radar waves to see through clouds, to shell electrons out of atoms to operate the new radios, televisors, multichannel telephone sets, and sound recorders, that I set no limit on the ability of nature, fundamental and applied research, and American industry to furnish what is wanted.

So, let the American citizen, or the citizen of any nation, make out a list of the things he would like to own. Let him list a car for every member of the family and a radio in every car if his imagination will not provide him with anything better. Then someone will ask, "Who is going to pay for all this?" It is a good question, but it shows ignorance of the nature of wealth. Our national debt, now touching three hundred billion dollars, merely involves the redistribution of purchasing power. And while it entails problems of its own, we are discussing now the over-all wealth of the South, of the nation, and of the world. Purchasing power means ability to get all of these things, these better products we are talking about, and involves only two things—energy, and the knowledge of how to control it. When people want better food, clothing, shelter, health, transport, education, security, and relaxation, they are presenting problems involving improved control of energy. After all, the cave man had all the iron, copper, and other materials necessary to make himself a fine refrigerator; and every single iron atom used in building our normal four million cars per year was present on earth in Archimedes' day. Why is the purchasing power of the American citizen twenty times as great as that of a Chinese coolie? You know that it is because he can produce more than twenty times as much output. He knows how to direct and control industrial power by the flow of energy. Increase the amount of energy he can control, and you can afford to increase his wages and his purchasing power. Each day the average American citizen consumes energy which, if produced by the human arm as used in pumping water or sawing wood, would require three daily shifts of thirty men each; that is ninety men working eight hours a day. The American citizen can have this energy because it need not be produced by the human arm, but is furnished instead by Diesel, steam, and gasoline engines and by electric motors.

Can the purchasing power of the American workman be further increased? Of course it can. There is no Malthusian law which says that the wealth of the world is so much and this is not enough to support more than so many millions of people. What sets the limit to social wealth at any moment? It is the amount of energy the average workman is able to direct and control effectively. Double this, and you double the national wealth level, the profit level, the wage level, and the purchasing power of the individual.

What sets the limit to our ability to direct energy? First, it is having the energy to direct, and here we need have no worries. We have always had thousands of times as much energy available as we have been able to control. Let the oil pools be exhausted in ten or a hundred years; let the coal fields disappear in one century or ten; forget about the uranium atom and other sources of atomic energy—if you can. Every day the earth soaks up enough energy from the sun to run all the industries of the world at their present rate for two hundred thousand days to come. Some of this energy we now use in water power and in farming, and I know of no scientist who worries much about our ability ultimately to learn how to harness a larger fraction of the remainder. Our wealth level can be raised two thousand times over what it is at present and still leave a greater than one hundredfold factor of safety. Research will show how best to direct and control this energy, and only research can bring us this wealth.

In conclusion, I congratulate you of the Southern Research Institute on the splendid start you have made. I hope, however, you will not sit back and be satisfied. Build up your industrial research and research in your universities and colleges, for in the long run the whole thing depends on one product—men of imagination. I cannot believe that in this product the South is not equal to any place on earth.