The plan followed was to inject saline suspensions of the crushed insects into the skin of *rhesus* monkeys. No verrucous nodules developed. At regular intervals thereafter cultures were made from the blood of the inoculated monkeys with a view to determining whether the Bartonella had entered the blood and multiplied in it. Four different lots of phlebotomi, as tested in this way, were proved to carry *Bartonella bacilliformis*. In the first instance the culture was obtained with blood withdrawn from the inoculated monkey on the 19th day, in the second on the 20th day, in the third on the 10th day, and in the fourth on the 42nd day. The inoculation of monkeys with the cultures thus obtained produced experimental verrucous nodules, with recovery of the Bartonella from the blood and the nodular tissue. The chain of evidence uniting Phlebotomus with Oroya fever and verruga peruana may be said to have been completed by these tests.

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THE RELATION OF RESEARCH TO WEALTH PRODUCTION[1]

WEALTH is produced by the performance of work upon the materials of nature as we find them on and in the earth's crust. In the term work is included not only the actual physical work done by men and machines, but also the work performed by capital, and this includes the use of money and of the facilities which money purchases. Wealth then represents an accumulation of something above actual requirements for maintenance and is usually represented by some form of money or negotiable exchange. The extent to which research contributes to wealth might, therefore, be discussed from the point of view of the increased possibility of producing from natural resources desirable commodities in excess of immediate requirements, and we at once think of the extent to which savings have been made in the physical labor required in carrying out the industrial program of the world.

While for the purposes of discussion wealth may be taken in this case as something measured by dollars, nevertheless the less tangible but equally important contributions of science to things cultural and even spiritual must not be overlooked, and because of these factors a complete evaluation of the contributions of science is well nigh impossible. To attempt to measure in terms of wealth as it is usually understood the value of a local anesthetic, the beauty of a synthetic color, the pleasure of a synthetic scent or the value of a medicinal produced from a coal-tar base becomes an absurdity. While statisticians have succeeded in arriving at figures which express the probable value of a life in terms of earning power or cost of development and education, we are still unable really to value a life in terms of money, and the close relationship between modern science and the life of our age makes it equally impossible really to measure the contributions of research to wealth, when considered in the broadest sense.

But to revert to the subject of eliminating drudgery, of doing by chemistry, physics and mathematics as applied to industry much of the work which formerly required endless hours of time. It is fairly well agreed that an enormous amount of human energy was expended in the construction of the pyramids and in beautifying ancient Greece and Rome, but it is doubtful whether any modern agency could afford to lavish the labor of hundreds of thousands of human beings on such an enterprise. It is only when the world is at war that such great blocks of labor are employed for a common end. In those ancient days slavery was held to be justified because slave labor enabled the patrician and the philosopher to have the necessary leisure to make their type of contribution to the welfare of the state. It is doubtless true that through the contributions of science the average individual to-day has an amount of leisure far beyond that experienced at any other period of the world's history, and an increase in leisure is almost directly in proportion to the contributions which science makes in the perfection of industrial processes and means for doing the world's work. Indeed, many hold that the vital problem of our times is the manner in which this additional leisure is to be invested, and we progress or retrogress as we employ this leisure constructively or destructively.

Our telephone companies carry some twenty billion communications a year, these messages covering more than fifty billion miles and involving work which if performed by messengers working nine hours a day, making a high average of ten miles per hour, would require seven million individuals at a cost of eleven billion dollars. The contributions of a long line of research workers enter and we see this labor performed by a few hundred thousand em-

[1] Read before the general session of the association devoted to the work of the Committee of One Hundred on Scientific Research at the Nashville meeting.

ployees of the telephone companies connected with something more than twenty-five thousand central offices and employing perhaps twenty million telephone instruments, the whole representing an investment of around two billion dollars and handling the business at one twentieth of the cost of the messenger service, even if we were able to employ so large a proportion of our working population for it.

Remembering to what extent paper enters into our civilization, it is well to note that if to-day all our paper had to be formed as hand-made sheets by the primitive methods still employed for some grades of special papers, a disproportionate number of our working population would be required to supply the more than one hundred and fifty pounds of paper per capita which America now consumes annually—a weight in excess of that of its total population.

Compare the rate at which holes may be drilled by the primitive flint-tipped drill operated by bow and string with the capacity of the modern tool-steel drill. Or consider the value of the contribution of modern lighting, or again the modern factory employing electricity, where one thousand workmen virtually direct the labors of an additional twenty thousand represented in the motors at their disposal. A slave power year to-day costs a little more than five dollars.

Explosives, a contribution of science, make possible works of construction so that a hundred men in ten months can accomplish what in the days of Claudius would have taken the labor of thirty thousand men over a period of eleven years.

Such examples could be multiplied at length, but the point of each illustration is the same. One way of measuring the relation of research to wealth is to measure the production which a given number of men can accomplish in a given time, thereby adding to the time available for other constructive efforts or for leisure.

That research creates new industries is equally apparent to any scientist who gives it thought. It creates them because it finds new materials and then devises ways to use them. These two steps are nearly sure to be separated by long periods of time, and some fundamental discoveries have had to wait a century to realize commercial development. The gradual employment of the gases in industry is an outstanding example of this, and but recently our attention has been called to how much argon does by doing nothing, reference being made to its assistance through the incandescent light, enabling us to obtain greater service for the dollar spent for illumination. The remarkable development of the sulfur beds which underlie portions of Texas and Louisiana is directly due to the chemical and physical constants of the element sulfur, determined as a piece of academic investigation. The fact that a stormy day in New York City is worth a million dollars to the manufacturers and retailers of raincoats and rubbers is due to Goodyear's contributions and to the numberless improvements in the technology of rubber manufacture, all of which are based upon fundamentals established through gradual and painstaking work in the research laboratory. Industries like the photographic industry have been established essentially upon a single scientific fact, and no industry would exist but for a firm foundation which science has built for it, though until recently unrecognized.

Whatever progress has been made in combating corrosion, it is not improper to credit research with the principal victories. But losses due to rust and decay will continue in staggering amount until the research laboratory determines why and how these materials of construction are destroyed or impaired. When we know the causes, it is safe to predict that corrective measures can be prescribed.

To a group of scientists it is idle to stress the part research has played in waste prevention and utilization. Every one can cite for himself and from his own field of experience abundant examples to establish the claim of research as a most potent factor in enabling man to use natural resources with the highest efficiency. There are classical examples in cotton products, in the meat-packing industry, in the cereal grains, in metallurgy and indeed in whatever way we wish to turn. That research has at times rescued established industries is also a claim that can be made with ample foundation, and it is noteworthy that the Welsbach mantle was of the utmost assistance to the manufactured gas industry through the period between the advent of the incandescent lamp and the more universal recognition of gas for power and fuel purposes.

That profitable industry is often revolutionized by the results of research is shown through the application of the principles of catalysis and surface phenomena in many lines of endeavor. To these may be credited such vast enterprises as the fixation of atmospheric nitrogen, the contact process for the manufacture of sulfuric acid, the hydrogenation of oils, the production of synthetic methanol, and much of the work that has been done abroad on the manufacture of petroleum-like bodies from gases derived from coal. It is useless to express the wealth represented by these enterprises, for the figures are great beyond our understanding.

What research means when applied to stretching the natural resources to keep up with world demands

is another service of inestimable value. What has been accomplished in increasing the productivity of agriculture, in preserving its products from one harvest to the next, and in the development of new species and varieties to suit particular locations and limitations of climate are but other reminders of the debt which civilization owes to those who work quietly and persistently in research laboratories and who for the most part are rewarded principally by the knowledge of a task well performed, by the plaudits of their fellow scientists and by a salary which too often is too meager to relieve them of financial worry.

There is always danger that a scientific man will claim too much for his efforts and while it is true that darkness has been banished, isolation broken, drudgery reduced, climate altered, the prospect of famines decreased, life extended and protected, and real poverty reduced almost to the vanishing point, it must be admitted that quite frequently the contribution of the original discoverer is but a few per cent. of the total effort involved in making the results available to people at large. There can be no development without the discovery, and yet the discovery must be followed by a great investment of time and money, in pilot plants, in semi-commercial-scale production, and ultimately in the provision of those facilities representing capital and labor which are the essential steps between the brilliant discovery of the scientist and the article which can be sold at a price to make it available to a great consuming public. The contributions of research to wealth, therefore, are so fundamental that it is difficult to claim too much, and yet with proper modesty the scientist may recognize how essential is the support of capital, labor, the public in general, if his research is to become useful. It is always well to recall the words of Millikan, that research to be justified must ultimately be useful.

All of what I have said and much more that could be said may be summed up very clearly, I think, by reference to the inscription on the beautiful dome of the building of the National Academy of Sciences and National Research Council in Washington. The logical development of the thoughts expressed in this quotation cannot fail to impress upon the minds of all, whether scientists or laymen, the key position which research occupies in the creation of wealth by whatever standard you care to measure it—"To science, pilot of industry, conqueror of disease, multiplier of the harvest, explorer of the universe, revealer of Nature's law, eternal guide to truth."

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FAMILY BUDGETS OF UNIVERSITY FACULTY MEMBERS[1]

FOR a long time the low salary of the professor has been matter of discussion. Those who deplore the relative smallness are sometimes in the profession, but more often are men and women in other professions. Of late, however, expressions of unrest have become very audible in academic circles, perhaps because of the rise in the cost of living and of the changes in the standards of living in all classes which now include even the conservative college professor. The younger generation of this profession is, I think, unanimous in believing that the salary now offered in the academic world, especially to its higher ranks, is not one that can fairly be expected to meet the needs of the professional family.

This assumption that, given the accepted professional standard of living, salaries usually paid university teachers will not meet family living expenses and that to maintain the standard, supplementary earnings or vested income, one or both, become necessary, seemed to invite verification by the test of expenditures. In 1923, a keen interest in the real facts behind such statements led the writer to ask a number of faculty members at the University of California to give help in testing the truth of the assertion that salaries did not pay for needs.

Requests were sent to the two hundred forty-seven persons who represented the married members of the faculty. One hundred twenty-one of these refused to participate. Of the one hundred twenty-six who accepted the invitation, thirty could not, for one reason or another, be included in the study.

By the beginning of February, 1923, ninety-six complete family schedules were available, a number which represented 50 per cent. of the married members of the University of California faculty.

Characteristically this group of ninety-six families was made up of men and women in the prime of life and of their descendants under sixteen. Sixty-two per cent. of the men of the families were somewhere between thirty-five and fifty years of age; their wives, slightly younger. The families were typically American, born in the north and west of the United States. On the whole, the households were of the modern "small-family" type. The size of family showed an average of 3.5 persons.

When the facts of income and expenditure obtained by the interviewers were tabulated and interpreted, the assumption that salaries do not meet the scale of

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