every industry, so it has permeated practically every fundamental science. In fact, it is not improbable that it may cease to exist as a separate science, just as reading, grammar and arithmetic have ceased to enjoy independent existence. As a result of further cooperation between subdivisions of science, science itself may perhaps become one subject. We shall then attain the final objective of all scientific effort.

INDUSTRIAL SCIENCE—A GILT EDGE SECURITY[1]

By MAURICE HOLLAND

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RESEARCH is one of the best forms of security for capital invested in industry. Efficient management is another. To a trained observer there is a direct relation between the research rating and the security ranking of the leaders of American industry. Turn to the financial page of your paper and read the names of industrial companies known as market leaders and you will find a list of those companies best known for their extensive research activities. Nowadays the discoveries of science is front-page news. The applications of science in industry appear in the business section, while the latest report of the advances of industrial technology are reflected in the quotations on the Stock Exchange. In the language of Wall Street, science appears on the financial page, when "the news is out."

Headlines that tell you of the latest happenings in the scientific world are primarily written, not to report the possibilities of prospective increases in profits or dividends, but to acquaint the whole public with facts that picture the march of progress. The science story appears on the front page for the reason that the achievements in the field of pure science are changing the face of the world. The story of what our scientists are doing and how they are doing it is much more than a story of financial success. On the contrary, it is fundamentally a story of advancing civilization, of higher standards of living, increased comforts, better health, easier working conditions, more leisure, in fact, of all the things that lead to the betterment of mankind.

One of the most widely read financial magazines circulates a questionnaire periodically to a fixed list of about 1,000 business leaders made up of presidents and presiding officers of corporations whose stocks are listed on the New York Stock Exchange. The winners in the most recent poll of corporation executives places the companies in this order: American Telephone, United States Steel, General Electric, Standard Oil, General Motors, Anaconda Copper, Electric Bond and Share, United Corporation, Radio Corporation, Westinghouse Electric and Manufacturing. A list of "Who's Who of Science in Industry" would contain the same names, with the exception of United Corporation, a holding company. The research activities of these companies have put them in first position, among the leaders of American industry, and research enables them to maintain that position.

In the highly competitive struggle for industrial supremacy, the march of science, discovery and invention has so speeded up the advances of technology that a laboratory discovery may mean creation of a new industry, or expansion of one and losses for another. To-day's discovery in the field of scientific theory inevitably leads to application in the practical field of business to-morrow. The slow process of evolution of industry by improvements in mechanical equipment has given way to revolution of manufacturing processes by research. Within the last year or two many industries have felt the rising tide of competition, and not a few have slipped from their moorings. The very foundation of industries, unless they be anchored in the bedrock of pure science, threaten to be carried away. They carry on under the silent menace of the attack of competitors undermining the structure with the levers of applied science.

This year's reports of some of the most progressive manufacturing corporations devote a half page of text or less to the finances of the company. The balance of the report is concerned with the achievements in science, invention and new processes and products which have grown out of them. The spirit of these reports is typical of the far-sighted policies which guide many of our successful industrial corporations. There is no more significant characteristic of present-day corporation management than its efforts to peer into the future, and their attempts to forecast future trends.

Leading bankers also have begun to realize that it is not enough to know the commercial and financial condition of an industry; they must also know the technical assets which lie behind the balance sheet, because plant, process and product may fall "victims" to competitive research.

At this moment analysts are busy searching out

[1] An address before the American Association for the Advancement of Science, at Pasadena, California, June, 1931.

basic factors; statisticians present arrays of factual data as proof of their theories; and bankers keep daily tab on the shifting currents. They watch the surface ripples of industry and commerce for a sign as to which way the wind is blowing. Statistics, barometer charts, market letters, business cycles, carloadings as indicators of the state of industry and commerce are accessories after the fact. They are based on past performance. They are about as good as "racing form" in predicting the performance of any dark horse in the race for industrial supremacy.

Forecasting industrial futures, by a study of the present trend of research, will be reduced by trained observers to the same formulae and computations which govern the transactions in cotton and wheat futures on the New York Exchange. In the not far distant day of "the technical or science audit" of an industrial company, barometer charts based on technical, not the commercial, state of industry will appear. The technical audit, as a supplementary safeguard to the protective devices now used in long-term industrial loans, seems to be inevitable development in investment banking.

Some of the factors behind the scenes of the company balance sheet which play important rôles are the technical state of the art, the plant, the processes and the product. The attitude of the management toward research, available research facilities and technical advances in foreign countries, which may influence the domestic market, all have a meaning to the eye of a skilled observer. These may be translated into the language of dollars and cents—deficits or profits, dividends or assessments.

In this age of mass production, big volume, quick turnover, the average American business man wants action. A quick return. His conception of research is that it is something like a mysterious box of black magic, in which you should be able to put a research appropriation in the slot, turn the crank, and dollar dividends would roll out. Compare that picture with the vision and business judgment which financed the "speculations" of academic-minded Ph.D.'s, and were rewarded with the control of the dye markets of the world by Germany. It took fifteen years of research and an expenditure of 29,000,000 gold marks to produce the formula for aniline dyes, a good illustration of "patient money."

Men called dreamers, seekers after truth, pushing back the frontier of knowledge, making fundamental investigations of sound in the Bell Telephone Laboratories, are the first-line defense in safeguarding the capital investment of the largest single industrial enterprise in the world. Six thousand research workers are kept in the field as prospectors on the frontiers of industry at a cost of twenty million dollars a year. Years of toil on the borders of the unknown may be rewarded with a mere handful of nuggets—in the form of new facts. But the discoveries of these new facts has shaped the destiny of old industries and created new ones. Pure science investigations to increase the volume and to refine the quality of sound for long-distance telephony yielded unexpected dividends. The minted winnings of research produced much fine gold, while further reduction brought out by-products from the lesser ore. One of these, fashioned by applied science to the pattern of a specific need, laid the foundation for the talking movies, and put the silent pictures on the shelf!

In those early days the moving picture industry did not support a single research laboratory within its own ranks. The industry is still paying tribute for an "imported technology." Sperry, of gyroscope fame, developed a high intensity arc lamp which is actually "brighter than the sun" and brings California sunshine to Long Island studios "sets"—with the snap of an electric switch. Such is the power of this man-made light that the motion picture screen is brought close to the movie fan in the last row of the highest gallery of our largest cinema cathedrals. Colored movies came out of the laboratories of two Boston Tech professors, whose patient plodding in the physics and chemistry of light and color enabled them to "break into pictures." They find themselves a little bewildered perhaps, in the world of make-believe, these advocates of truth who practice in the court of nature, where there are no appeals, nor any exceptions granted. Their names have never "gone up in electric lights." The record of their achievement lies buried in laboratory notebooks, transitory guideposts on the path of progress. To-day there are more experimental laboratories on the movie lot than studios, and there are more technicians in Hollywood than actors.

The moving picture industry, working with a dynamic medium, is growing up, technically speaking. This industrial prodigy is one of the youngest in the large family of science-aided industries to emerge from the laboratory incubator, where the "children of science" are born.

It is almost axiomatic in the experience of the division of engineering and industrial research, N. R. C., that new industries, with processes in the state of flux, and with management unhampered by tradition and prejudice, are the most likely prospects for research. Radio and commercial air transport are also good illustrations of the lusty brood of the twentieth century generation of industries which have opened the door of opportunity with a science key!

Part of the broad policy of up-to-the-minute man-

agement of our industrial corporations is the eagerness with which far-sighted executives watch the developments of science. No advance in industrial technology is overlooked which may be turned to good account. With news reels bringing the latest "flash" reports from every corner of the science world, with popular science radio talks recording almost daily the triumphs of the test-tubes, in the battle for industrial supremacy, science is working in glass houses—that all may see. Industrialists not content with watchful waiting have become some of the most substantial contributors to the advance of pure science as well as to the technology of their own industries. Every year more and more laboratories are being set up, and the scope of their inquiries is steadily broadening. A National Research Council survey of 1920 lists 575 laboratories. By 1927 there had been a hundred per cent. increase, with over a thousand laboratories operating, as an integral part of the private industrial companies. To-day there are over 1,600 industrial laboratories. They serve as the far-flung outposts of American industry on the frontiers of knowledge.

To prophesy that any addition to the body of human knowledge will never be of any practical value is extremely hazardous. Who will say that Einstein's theory of relativity may not be the bedrock foundation on which a dozen industries as yet unborn may be erected in 1975? Who will be so rash as to predict the final result of the recent meeting of the world-renowned mathematical genius with Michelson and Millikan, both of them Nobel prize winners in physics? Hale, working in his "laboratory on the sun," brought down to earth helium, which has since been used in the building of fireproof dirigibles which have spanned continents and crossed the seven seas. Hardly two quarts of helium was known to exist on earth as late as 1914. Sometime ago this rare gas, discovered by dreamers gazing at the stars, was a cure for "bends," a temporary paralysis caused by working at great pressures which overcomes men burrowing in the earth and diving into the depths of the sea.

Science owes much to the modern tendency of the increasing use of science in industry and the debt is steadily increasing. The fruits of the applications of science provide the seeds with which to endow the planting of new gardens in which pure science may come to full flowers. Industry profits immeasurably by its vision in this direction. The testimony of the executive officers of a thousand representative industrial corporations, rated in the million-dollar class, is conclusive that research is a paying investment. Here a few typical statements are presented.

The president of a chemical manufacturing firm answers in no uncertain terms. "Research," he says, "is the one tool by which, within the short space of 12 to 15 years, American chemists, engineers and physicists have established in America an organic chemical industry, the magnitude of which is so great and the quality of whose product is so good that it is the marvel of our European competitors. In this field, the country to-day is practically self-supporting, as compared with the situation before the War when it was practically dependent upon European supplies."

In a different field of industry consider this statement made by the treasurer of a large textile plant, "We can figure that our leading profits are from 100 to 200 per cent. of the amount spent for research."

Another executive who has apparently determined his profits from research closely (he is vice-president of a rolling mill and steel concern) declared: "For every dollar spent in true research we have reduced costs and increased net revenue by at least $100." A particularly enthusiastic pulp and paper manufacturer has found his research laboratory "the biggest dividend-paying department."

The average annual premium paid by this representative cross-section of American industry is 1.3 per cent. of capital investment. Research appropriations are regarded by these executives as industrial insurance against competition. As an average for all industry, 31 per cent. of the investment in research is directed towards reducing production costs; 34 per cent. to improving the quality of products in service; and 20 per cent. to developing new fields of application; while the balance of 15 per cent. is used for developing new materials and products. The principal emphasis of research programs is on developments and improvements that will gradually improve production and increase dividends for the long pull. The public as a whole is the greatest gainer of all. The ultimate dividends of research are passed on to the consumer in reduced costs, improved quality and service and in dividends.

Industrial corporations, like industrial securities, may be divided in two major groups—preferred and common. Preferred securities attract the investor, primarily interested in the safety of his principal and a steady and assured income. Common stocks are conceded to be speculative. The public interest in investments in American industry is much larger than most of us realize. It has been estimated that there are fifteen million stockholders of industrial securities. No single investor in American Telephone in the legion of 550,000 stockholders in that company owns 1 per cent. of the stock. U. S. Steel, General Motors, General Electric and Standard Oil pay dividends to 600,000 or more "individual bankers" who have chosen to share their fortunes with these "indus-

trial giants." Recently an investment trust was organized in which investors were invited to share in futures of a representative group of industrial corporations, each of which is an acknowledged leader in its field. Every company in the group operates a research laboratory as an integral part of the company organization. The names of forty companies read like a blue book list of "Who's Who in Industry." The "and why" is summed up in the one word "research." The sponsors of this "trust" look upon research as an industrial security in this way: "Scientific research as it affects the industrial survival and competitive race of great companies, whose histories are measured by decades rather than by years, is a method—not a catchword, and in its place it is as important as methods of selling, production or accounting, although not quite so immediately effective." That statement would indicate that investment bankers and their customers, the investors in industrial securities, have begun to appreciate the meaning of "patient money."

Banking also takes a first-line position on the frontier of industry. The adventurous spirit of research opens up new territory, banking consolidates the position. The enterprise of research workers stakes out the claim; banking supplies the capital, to bring out the pay dirt. Research is a guarantee to the banker of invested capital, his insurance against loss in new enterprises. Research blazes a trail as the vanguard of industrial progress; banking builds a road to connect the frontier of industry with the main arteries of commerce.

OBITUARY

MEMORIALS

IT is reported in *Eugenical News* that at Neu Titschein, Czechoslovakia, near where Gregor Mendel was born, there was held on July 5 a celebration at the unveiling of a Gregor Mendel monument. The program was as follows: Professor Dr. Oswald Richter, of Brünn, gave an address on "Gregor Mendel and His Home," and Hofrat Professor Dr. Erich Tschermak-Seysenegg, of Wien, on "Mendel's Laws of Heredity and Their Significance for Plant Breeding." An address of welcome by Burgomaster Dr. Ernst Schollich, and an address by Professor Dr. Frimmel, of Brünn, was followed by the unveiling and a chorus. At 4 P. M. there was an "Ausflug" by auto to Mendel's birthplace in Heinzendorf.

THE review *Scientia* pays tribute to the memory of its late director, Dr. Eugenio Rignano, by founding a Eugenio Rignano Prize, of the value of 10,000 lire, to be conferred by international competition upon the author of the best essay on "The Evolution of the Notion of Time."

RECENT DEATHS

PROFESSOR EDWARD S. KING, professor emeritus of astronomy at Harvard University, died at his home in Cambridge on September 11 at the age of seventy years.

PROFESSOR RUSSELL LOVE MORRIS, professor of engineering at West Virginia University, died on September 1, at the age of sixty-two years.

MR. COURTENAY DE KALB, well-known mining engineer and former professor of mining engineering at the University of Missouri and the University of Alabama, died on September 2 at the age of sixty-nine years.

MR. EVERETT JOEL HALL, formerly professor at the School of Mines at Columbia University, died on September 3 at the age of fifty-four years.

DR. HENRY T. MCKINNEY, professor of education at Bethany College, died on August 30, following a minor operation. Dr. McKinney, who was treasurer of the West Virginia Academy of Science, was fifty-two years old.

SIR THOMAS STANTON, superintendent of the engineering department of the National Physical Laboratory, England, was drowned in Pevensey Bay, Sussex, England, on August 31.

DR. ARTHUR SIMARD, professor of surgery at Laval University, Canada, and past president of the College of Physicians of the Province of Quebec, died on September 3. He was sixty-three years of age.

PROFESSOR J. W. HINCHLEY, professor of chemical engineering in the Imperial College of Science and Technology and secretary of the Institution of Chemical Engineers, died on August 13 at the age of sixty years.

SCIENTIFIC EVENTS

THE AMERICAN CELEBRATION OF THE ANNIVERSARY OF THE INVENTIONS OF MICHAEL FARADAY AND JOSEPH HENRY

THE one hundredth anniversary of the discovery of electromagnetic induction will be observed by an elaborate display sponsored by the New York Museum of Science and Industry and the Radio-Electrical World's Fair. *The New York Herald Tribune* reports that the display, honoring the achievements of Michael Faraday, the English physicist, and Joseph