tryptophane, these being imperatively needed for the building of tissue and for making good the losses of cellular material. Hence, proteins which are lacking in these indispensable amino-acids, or contain them only in small amounts are physiologically inferior proteins, not fitted to meet the needs for proper growth.

But I must not continue longer. To cultivate research and thus promote the advancement of knowledge, to bring to light a new truth, in whatever the field of endeavor, is to the true scientist one of the great joys of life. As a recent writer (A. V. Hill) has expressed it: "In scientific research we work and work, sometimes for months and years, in digging a tunnel with no apparent results; then suddenly comes the supreme joy of life—daylight begins to glimmer at the end, and in a few minutes we see that nature, after all, has not played us false."

THE NEED OF COOPERATION IN BIOCHEMICAL RESEARCH[1]

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A CONTINUOUS teaching and research contact with scientific workers in an academic atmosphere, such as has prevailed at Yale for the last thirty years, is an experience not to be enjoyed by many teachers. An active man could hardly fail to have been influenced by what has happened within this period of time, and also benefited by the many associations that such a professional career offers. It has been the writer's good fortune to have enjoyed such an experience, and he is not able to properly express his appreciation for the satisfaction and pleasures which he has enjoyed in many ways during the past thirty-one years through his associations with graduate students and cooperative undertakings, in the promotion of Yale's activities and productions in chemical research. Although it is nearly one third of a century, it has all happened so quickly that it is difficult to realize the significance of the advances that have been made in our knowledge of the field of chemical science and to comprehend the possibilities of discovery in the newer fields of research which have been opened up to the organic chemist within this period of time. There is no doubt that the younger men who have in their control the destinies of the next thirty years of scientific service have before them opportunities for successful accomplishments which are just as promising as the future held out to young investigators at the beginning of this century. We older men do not begrudge these new recruits to our ranks their rich opportunities, but we wish them the best of success, and with the hope that our accomplishments of the past thirty years will have made their course less difficult to follow, their problems easier to understand, and their methods of attack and conclusions more exact and definite.

[1] An address delivered at the Conference for Investigators Interested in the Chemistry and Physiology of Plants, at New Haven, Connecticut, June 5, 1931.

The last half century has seen a great advance, not only in the development of every branch of the natural sciences, but also in the number of these branches. It has been a growth which has necessarily led to much specialization, but not without great benefit to all the major divisions of the natural sciences.

The names of the new sciences, for example, such as geochemistry, biophysics, biochemistry, astrophysics, psychophysics, and many others, which we have not time to mention here, show that these new subdivisions are merely the overlapping of two or more of the older branches of science. Their fields of operations are the border lines of different sciences where the phenomena of natural interest are dependent on fundamental laws characterizing the special sciences involved. What has been the result of this overlapping?

(1) One result has been a breaking down of the old boundaries of science and a more general recognition of the scope and application of the theories and principles of the science of chemistry. To-day there is no definite boundary between chemistry and physics, between chemistry and crystallography, between chemistry and metallurgy, or between chemistry and technology.

(2) It has meant also that we have developed a highly specialized knowledge which now requires a much broader basis of scientific training than it did thirty years ago. As a result we have been called upon to give more thoughtful consideration to the preliminary training of those who desire to prepare themselves for professional careers and to pay more attention to the proper coordination of fundamental course subjects and to emphasize the dual nature of the major scientific projects now calling for investigation and solution.

(3) And, finally, it has caused to be evolved a new

program or era of sympathy, understanding, general appreciation of the importance of all research and interchange of ideas between workers in different fields of science. No scientific group of workers can live to-day within itself and accomplish its best work. We are all more or less interdependent and we are living in an age which is changing rapidly, and quick decisions are expected. This urgent demand for prompt solution and more rapid progress is calling for increased concentration on the part of the investigator and a greater amount of cooperation than ever before. Closer organization seems to be the demand of our times, and the bringing together of different workers in the fields which overlap is essential if we are to accomplish our best work.

No science has been more affected in the scope of its interest by these developments than chemistry. The specialized subdivisions of knowledge, such as biology, bacteriology, animal and plant physiology, botany, pharmacology, medicine, surgery, psychology and even some subdivisions of the social sciences, can no longer dissociate themselves from its influences. Chemistry was once confined to a few individuals and used in a few industries only. It is now widely diffused in all scientific undertakings dealing with natural phenomena and is used in practically every industry. No one can study to-day any modern science or branch of technology, mathematics alone excepted, without some knowledge of chemistry. In fact, in a few years' time every person that is considered properly educated will have a smattering of chemistry, and furthermore, no chemist will attempt to be interested and informed in all the several branches of chemistry. Procedures that have suited in the last fifty years will require much modification to meet the growing demands and to suit the next fifty years.

The technical and scientific world was never more interesting to investigators and the public than it is to-day. Discovery follows closely on the heels of discovery; theories and speculations live only for a short time. Industry to-day is in a state of constant strain. Processes that lead to a financial success to-day become impractical or obsolete to-morrow. In the hands of the engineer or technologist lies the secret to-day of success in all our industrial enterprises. Every discovery depends upon previous work. Every stage in the unfolding of knowledge prepares the way for further advance.

The most outstanding development in the biological sciences, from a biological or a chemical point of view, has been the growth of that field of scientific endeavor that we include to-day under the subdivision "biochemistry." It was not, however, until workers in the different biological subdivisions began to realize what chemistry could do to aid in the advancement of the knowledge of their respective subjects that cooperative measures were finally instituted, which led up to the important developments grouped under this new branch of science.

That all vital activity is dependent on chemical reactions is a belief which has influenced the growth of organic chemistry for years. Chemists have been interested for a long time in elucidating the chemical mysteries of the living processes of animals and plants. The French chemist, Lavoisier, in the eighteenth century was one of the first to express an interest in the phenomenon of respiration, and he stated that animal heat results from the action of oxygen. As a result of his postulations the direct method of oxidation was thought for a long time to be the only one to which the phenomenon of respiration could be ascribed. Later, this conception of respiration and fermentation was shown to be untenable when Pasteur, a chemical-bacteriologist, demonstrated that microorganisms could exist and propagate their form without free oxygen. In fact, he went so far as to show that oxygen acted as a poison and was harmful to some of the lower forms of life. We now recognize as a result of his work that this gas must be excluded if anaerobic organisms are to grow and multiply. In fact, Pasteur regarded fermentation as anaerobic phenomenon. To-day these pioneer conceptions of respiration phenomenon no longer hold. Our ideas have been revolutionized by the new discoveries in biochemistry revealing a more exact understanding of cellular oxidation-reduction changes. This has been the result of three broad chemical influences: (1) A better understanding of the chemical composition of cells and their process of metabolism; (2) an advance in our knowledge of the physical chemistry of organic reactions in heterogeneous systems and the experimental conditions affecting intermolecular transformations; and (3) the discovery of the fundamental laws governing all colloidal and interfacial phenomena.

Emil Fischer's classic contributions to our knowledge of the chemistry of proteins and sugars, van't Hoff and Le Bel's brilliant speculations which led up to the modern physical conception of the asymmetry of carbon in organic combinations, and the recent revelations of organic structure and crystal constitution by application of x-ray photography are illustrative examples of the many classic contributions to chemical science which have finally established firmly the architectural theory of the molecular structure of organic compounds. Every branch of natural science which has called upon organic chemistry for cooperation in the development of its border-line problems has been influenced by this structure theory conceived by the early workers in chemistry. The

theory of organic structure has been fully substantiated and it has stood the test of experimental science for the past sixty years. It is now recognized as being in complete accord with the exactness, precision and regularity of all natural biological phenomena.

In other words, chemical-biology, or biochemistry, has assumed a particular distinction to-day as a field of science which gives it a much broader significance and scope of operations than can be ascribed to any single subdivision of science. It represents in modern language a community of scientific interests having interdependent relations, and no one of the fields of study embraced under this term can function to-day independently.

We can, therefore, no longer divorce chemical from biological reasonings. All the branches of biological science are becoming more and more closely connected with the facts and theories of chemistry as new discoveries are made and our technique is improved.

If it be admitted that this consolidation of chemical and biological interests is necessary for future growth, and will lead to an increase in our knowledge of natural phenomena, is it not a logical conclusion that the future workers in these related fields should be urged to cooperate more closely in their work, and seek to better understand the view-points of each other—in other words to be able to think and reason together? The contact can not be otherwise than helpful. Professor George Barger, of Edinburgh, Scotland, remarked in a recent address as follows: "I am convinced that within the limits of administrative possibility the greater the variety of workers brought together the better the results." This is most essential to-day if different workers in two or more correlated scientific fields are not to be deprived of much valuable interchange of ideas, of essential materials for experimentation and new apparatus for developing technique.

This does not mean that the discoveries made by individual and isolated workers who desire or are compelled to work alone will be without value in the final solutions of our many problems. We all know that we have scientific workers who are so constituted that they can do their best work independently and will be exceptionally brilliant and capable of contributing largely to knowledge oftentimes in more than one scientific field. Nothing should be done to interfere with or restrict the activities of such investigators. They represent an important unit of our scientific personnel, and many of our soundest conclusions are made under such conditions.

One could expand further on the subject of all-around genius, and of the few men who are able to make discoveries of far-reaching effect in whatever branch of science they took up. Notwithstanding all this, it is undoubtedly true that the amount of scientific data made available by such men will be much smaller and less comprehensive than that which is contributed by workers organized on a cooperative basis. This has been well illustrated by what has been accomplished within the last six years in the field of tuberculosis research, and many other illustrations could be given to support our thesis.

A biochemist requires to-day a thorough grounding in physiology and organic, physical and colloid chemistry as well as some acquaintance with diverse subjects like botany, and even pathology. In fact, the important problems calling for solution to-day demand a close cooperation between chemical laboratories, plantations, forest and field, and require the services of men of considerable intellectual ability, a capacity for careful and sustained observations, and ability to select data with good judgment and a liking for life in open competition.

It is significant that at the present time a steadily increasing number of trained organic chemists consider it worth their while to turn to biochemistry for their future work. They are apparently welcomed into the ranks of such service, and the future holds much in store for them. The development of chemistry in elucidating the mysteries of living plants and animals is the most attractive field of research for the next generation.

Our future investigations will involve the inner structure of matter, radioactivity phenomena, nature of magnetism, utilization of electrical charges, conversion of these into heat and their effect on life itself. Progress will be made if our educational system will enable us to develop researchers of intelligence, gifted with the ability to observe, who have a good eye and show skill in manipulation.

A great deal is known about the biochemistry of the body, but a great deal is obscure. At present the line of progress seems to lie in the isolation, identification and subsequent synthesis of products produced by cells of the body and plant. But how much is actually known about the chemical activities of the vital source of biological phenomena—the living cell? We all realize that we are dealing here with delicate problems, but we are optimistic about the future results. The chemical compounds regulating animal life are being slowly and surely identified and the chemical processes they cause are now being watched and explained. The chemistry of bacteriology, of simple botanical life, of fermentation, of drugs and alkaloids useful for treatment of disease and enzymic processes now form some of the important branches of the science of biochemistry.

To summarize: Just as chemistry has permeated

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.