be closely analogous with that of chemistry. However, the knowledge of heredity and the casual accomplishments in hybridity already realized would probably make attainments considerably more rapid.

Mutations (neo-Darwinian variations) range from the ordinarily imperceptible, though possibly quite potential under circumstances of hybridism, to those of considerable magnitude. They are of multifarious, chance kinds and utterly without objective. Each new mutant gene in practically any group of higher plants or animals proportionately greatly augments the probabilities of supervenient hybrid emergents. These, in turn, are as much fortuitous sorts and without direction, or objective, as the mutants themselves.

Wheeler states "that there is not on the planet a single animal or plant that does not live as a member of some biocenose." It is likewise probably true that there is no single bisexually reproducing animal or plant which is not in some essential features a supervenient emergent of hybrid syntheses. Hybridity has probably been the efficient, ultimate agency by which the mutant characteristics of all varieties and races of bisexually reproducing organisms, including man, have attained whatever casual, eventual grade of supervenient emergency they may have severally occupied, whether they were among the preponderant legions below the point of ability to survive, those in the situation of being merely tolerated, or the comparatively small numbers which appear to have been reasonably well adjusted.

Natural selection creates nothing; it is strange that anybody ever misunderstood or misstated Darwin to the effect that it does. Mutations and hybridity furnish the materials, mainly, perhaps among the higher organisms wholly, in the form of supervenient individual hybrid and biocenose emergences of fortuitous kinds and without objectivity or direction. The vast majority perish, some linger awhile, others are suffered, while presumably relatively few are fairly well adapted to the dynamic, intra- and interpermeating complexes of the environment; which encompassing complexes are, in turn and in their aspects, as much supervenient emergences as are the intra- and interpenetrating organisms and societies they environ. Here, then, are the exclusive field and materials in and on which it is considered that natural selection operates.

We are probably not yet in the position, certainly it is not intended in this paper, to estimate the share, if any, that should be allotted to hybrid emergence as here defined, in the consideration of the causes of evolution. Bateson's challenge apparently still stands unanswered, at least experimentally; no one has yet demonstrated, either through hybridism or by any other means, a method by which progeny may be derived which are fertile among themselves yet which do not produce fertile offspring when mated back to the original stock.

We are still in a morass, it may as well be admitted, with regard to the ultimate problems of evolution. However, de Vriesian mutations (neo-Darwinian variations)—possibly irradiation-induced mutations, hybrid emergence (emergent evolution) and natural selection constitute features of a rough path, a sort of crude track through the jungle, beaten by Darwin's seven-league boots, that may soon open into somewhat of an upland clearing from which a further reconnaissance may be made.

BIBLIOCHRESIS: THE PILOT OF RESEARCH

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Whereby the sedulous worker
His laboratory course does steer.

BIBLIOCHRESIS, the scientific use of literature, has the pilotage of all scientific investigation. It has, in fact, the same relation to research as the latter has to management; it is the intelligence service of all orderly inquiry, the preparational agent of factual determination, the guide of experimental trial in eliminating chance, in the whole realm of science.

To be scientific, an investigation of any type must be made methodically—a condition that requires, primarily, that all scientific research be conducted in the light of recorded experience. This requirement applies to the exercise of the historical and analytic procedures of investigation as well as to the employment of the experimental method, whose use, whether for confirmation or for original work, rests upon prior knowledge and art, *i.e.*, accepted practice.

Bibliochresis, then, is the most indispensable tool in laying the foundation for scientific research. Since it enables the qualified worker to find the experience of his predecessors, as recorded in the literature, it confers upon him either the power to predict the results of effort—this is the outcome if the recorded information is evidently factual, *i.e.*, definite and confirmed—or the ability to plan further research on the same or an analogous topic. Reference is had throughout this communication to the proper use of the results of bibliochretic study and not to the incor-

rect employment thereof in the place of indicated experimental investigation. Bibliochresis is never a substitute for needed laboratory research.

The collection of recorded experience—the function of bibliochresis—is plainly the provision of data for facilitating scientific decision and for projecting research. The factual information thus acquired is the groundwork for the comparison and measurement that compose analytic research; it is also the foundation for gaining the new ideas that characterize invention and discovery. Continued progress in science became possible only when the development of the art of printing enabled investigators to make use of the recorded observations of other scientists.

The necessity for a literature search as a prelude to experimental investigation, either disinterested or industrial, has long been an axiom of the scientific professions. The importance of this first step has often been stressed, but rather as a policy of pedagogical value than as a defense of the procedure. Laments at the increasing volume of scientific literature have become hackneyed, demands for more efficient abstracts and reviews have become strident, but these various voices have not been raised against the value of an intimate knowledge of previous researches in a given field.

The wastefulness of needless repetition of experiments already described in the literature and the concomitant inefficiency that allows pertinent experimental findings to remain buried in the library were deplored in a recent editorial in *Nature*.[1] The *Engineering and Mining Journal*,[2] aroused by this article, questioned vigorously the advantages of a literature search as a preliminary to experimental investigation, particularly when a novel technical achievement is the goal. *Metals and Alloys*,[3] a welcome new periodical, has no less firmly taken its stand beside *Nature*.

Of the men best qualified to analyze the factors that lead to high scientific attainment—research directors, personnel managers, experienced investigators, technical editors, educationists—few will deny the necessity of library studies as a discipline for the self-conceit of the researchful mind. The scientific societies and organizations and the philanthropic agencies for the advancement of science have been unanimous in recommending increased use of existing facilities and concerted effort to improve the technical libraries throughout the world. Very recently an officer of the National Research Council has expressed the view that there should be a good working library of science in each educational and industrial center. Such a library would require an initial outlay of at least thirty thousand dollars and a minimal annual expenditure of one thousand dollars thereafter.

The opinion of these authorities concerning the value of bibliochretic work and opportunities is confirmed by several facts.

(1) Bibliochresis occupies a prominent place in the curricula of research training schools. For example, a number of universities are now giving courses in chemical bibliography. Among the text-books dealing with the subject wholly or in part should be mentioned "The Literature of Chemistry," by Crane and Patterson; "Chemical Publications," by Mellon, and "Introduction to Organic Research," by Reid. "Medical bibliography" is another pedagogic innovation.

(2) There is a constantly increasing demand in industrial laboratories for chemical bibliographers, other scientific literary specialists and chemical economists.

(3) The recognition of the need for bibliographic material in compact form is shown by the demand for indexes to the literature, as evidenced by the large number of orders received by their publishers.

(4) Satisfactory incomes, considering everything, are enjoyed by a number of practicing bibliographers who specialize in preparing, for stipulated fees, select bibliographies and also reviews of the journal and patent literature.

(5) Many men have been found to be unsatisfactory in industrial research because of their lack of knowledge of elementary bibliochretic procedure. How often in our personnel work we have seen the criticism of a referee of a candidate to the effect that the latter "was not able to work with ease and interest in literature searches" or "was replaced by a better man because he could not be depended on to make a thorough survey of the literature."

(6) Systematic bibliochresis is the means of establishing authority and originality, in science as well as in history and jurisprudence.

In discussing the subject of bibliographic studies from a broad point of view, several varying requirements must be taken into consideration. The type of literature survey best suited to any given problem must be decided, of course, in each particular case. There is, so to speak, a law of diminishing returns for library work. The handbooks, monographs and other reference manuals give a maximum of information in a minimum of time. When the search is projected into the original literature, the information to be obtained tends to become more and more diffuse as the quest is made more thorough. "Bibliography is as complicated as anatomy, as intricate as physics, as certain as history and as interesting as life itself," is the view of a great medical educationist.

[1] *Nature*, 122: 913, 1928.
[2] *Eng. Min. J.*, 128: 383, 1929.
[3] *Metals and Alloys*, 1: 197, 1929.

Bibliochretic lists and indexes are often prepared by general agencies for the promotion and encouragement of research. All administration of the proper type must rest on factual information, and hence any methods that facilitate the location of facts are shortcuts to sound management. In providing these indexes, which are of great value as starting-points for bibliochretic studies, such organizations are performing an important service, particularly because it is becoming increasingly difficult to arrange for the publication of material of this kind through the scientific press.

Among the most valuable bibliographies, or classified reference lists of literature, should be mentioned those of C. J. West, of the National Research Council. His "Bibliography of Bibliographies on Chemistry and Chemical Technology," prepared in collaboration with D. D. Berolzheimer, and "Bibliography of Pulp and Paper-Making" are examples of some of the important contributions he has made to the classification of ultimate sources of knowledge. E. H. McClelland, head of the technology department of the Carnegie Library of Pittsburgh, has produced several bibliographies, especially in the realms of ferrous metallurgy and fuel economy, that are classical in their accurate scope. At one time the Smithsonian Institution subsidized the publication of quite a few bibliographies; in chemistry the original aim was to index all the books and periodicals and also the special literature of the elements and of certain important compounds.

Noteworthy examples of bibliochretic studies, or critical indexes of the literature, as they might be termed, are found among the monographs sponsored by various technical organizations, such as those of the American Chemical Society. These books give not only comprehensive lists of references to the original literature, but the author in each case, usually a dean of the investigators in his field, unifies and summarizes impartially the experimental contributions that have been made. The constantly increasing cost of publication and the lack of space due to this factor as well as to the large number of papers that come before almost every editor for consideration have led to the existing preference for select bibliographies. These condensed indexes also save the time and serve the needs of the average reader.

There is considerable difference in many cases between the character of the library work appropriate for academic and that for industrial research. In the field of pure science, searching literature studies are made more or less as a matter of course. Such work is for the most part carried out in universities or research institutes with good bibliographic facilities and with somewhat more deliberate an atmosphere than that in an industrial laboratory. There is usually a professor or research director to plan the investigation, which is generally for a thesis. The problem selected must be reasonably free from overlapping studies in order that the junior author may be assured of a research publication; he is supposed to publish a paper to fulfil all the requirements for his degree, or, at least, he is eager to be able to treasure reprints of an addition to his short list of papers. In either case, the disappointments aroused by finding that his efforts have been dissipated on something already worked out is not to be taken lightly by those who are training our youth for enthusiastic scientific careers. Then, too, his own efforts to make use of the library are not to be overlooked. An exhaustive bibliography is an essential part of his thesis (and it is to be regretted that more theses, with their extended bibliographic studies, are not available for general use). In his conversations with fellow students he incites them to destroy the historical background of his work. Finally, when the completed article is submitted to a journal, a board of editors jealously guard against the duplication of a previous publication. It must be remembered also that the literature pertinent to a problem in pure science is likely to be more easily located than in the case of an industrial project. In spite of all these precautions, unwitting duplication of results is not unknown.

The bibliographic problems of the industrial research man are much more complicated. He is expected to use his time to the best advantage. He must work in libraries that, as a rule, are not so thoroughly stocked as those of the universities, although this condition is being improved markedly. The literature of industrial science is more difficult to follow: the journals for both the technical and pure science publications must be examined; the patent literature must be much more carefully searched than in the case of pure science research; the publications of most interest to him will often contain veiled meanings, and finally, the things for which he is searching may have been done but never published. This last possibility is of the greatest importance in connection with supposedly patentable processes and products.

There are, it is true, some scientists in both pure and applied research who have been eminently successful in spite of the fact that they have purposely refrained from systematic use of the existing literature. They are usually of the genius type, men of great originality and resourcefulness, who would have achieved fame in any field. A noted scientist comes to mind—a heroic figure, inspired, intrepid, a veritable lion of research, yet withal a kindly philosopher

whose personal charms have endeared him to two generations of students. His views are that a methodical, mechanical bibliochretic survey cramps his imagination, that it often turns him from profitable paths of research, that he has never been able to duplicate exactly any one's results and, finally, that to him the never-ending joy in scientific work is in finding something he did not know before, even though it might have been found previously by many other workers. Few of us can attain to his heights. As time goes on and the various fields become more and more thoroughly worked over, genius will find it increasingly difficult to assert itself.

It seems to us that the attitude of mind of the man who can achieve continuous research success without using the literature systematically is susceptible to further analysis. He has a profound knowledge of his specialty and he keeps in touch with current progress, although in a desultory fashion. His self-confidence is maintained by his achievements as well as by his grasp of the field. He can therefore plan new work by visualization with reasonable accuracy. Self-satisfaction with his procedure comes to him through his success.

All of us sympathize with this attitude, but it is more than questionable whether it should be encouraged as a matter of general practice. The position of the scientist in the world has changed; he is no longer an unimportant person following the vagaries of researchful imagination, but an important factor in the economic life of a country. Neither industrial laboratories nor research institutions would subscribe to the view that a scientist has fulfilled his duty if he gratifies his personal curiosity by rediscovering old facts merely because he has been too unsystematic to search the literature.

An aspect of bibliochresis seldom emphasized is that, in the hands of a specialist endowed with imagination, trends in research can be analyzed and forecasts can be made with a reasonable degree of probability. The worker can avoid fields in which, from a survey of the literature, it appears that too many groups of workers are engaged to give promise of marked success if he starts in, far behind, to catch up with the others. On the other hand, a particularly keen man can sometimes perceive an important goal which the mass of workers have been too preoccupied to see.

The scientist, scorner of riches though he may be, almost invariably has a certain respect for the acumen and enterprise of the successful business man. The world of affairs, on the other hand, although somewhat awed by the researcher, usually regards him as impractical. It is somewhat paradoxical that the great strides made in business practices during the present generation are in large measure due to the introduction of the scientific method into managemental procedure. Library research has played an important part in all such changes.

Nor has scientific management been neglected by the industries based on science. Before the war there were few persons who could qualify, for example, as chemical economists, but in this respect other fields of management were no further advanced. Now we find in every branch of industry economic surveys of unsurpassed excellence, and the technique of collecting and analyzing such important data is advancing continuously.

Organization is characteristic of the age. All human activities are becoming more and more a matter of coordinated regulation. The dietetically chosen food we buy on a budget plan from a chain store has been systematically approved by city, state and national health officers; it has been distributed, with or without intermediaries, to the retailer according to his calculated sales volume by the manufacturer, who has prepared its reception by scientifically executed advertising; it has been transported over railroads whose interrelations are controlled by governmental regulation based on economic reasoning; the raw materials were selected by means of standardized tests; even the ultimate producers are now being more and more firmly knit together by the economic necessity for management on scientific principles.

The same spirit of organization hovers over the research laboratory, which creates such products. The haphazard methods of the inventor will experience increasing difficulty in competing with organized research, both in pure and applied science. As the literature increases, more and more critical studies will be required, and still larger research units will be obliged to correlate their efforts to avoid duplication. It is not the time to urge less use of the library, but to encourage research workers to follow the literature as never before.

OBITUARY

STEPHEN ALFRED FORBES—A TRIBUTE

ON March 13 Professor Stephen Alfred Forbes passed away at Urbana, Illinois, after a brief illness. His end was no doubt hastened by the death of his wife, which occurred on January 24. Despite his eighty-six years, Dr. Forbes was active until within a few days of the end and at the time was the oldest servant of the state of Illinois, which he had served