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A Neglected Aspect of Scientific Research.

IT is unnecessary to stress the vital importance of research in the development of industry. It would be admitted generally that the intensive application of the scientific method is necessary in order that British manufactures may compete successfully with foreign goods and increasing exports lead to the mitigation of the terrible evil of present unemployment. Although the business application of economic laws is leading to the merging of commercial organisations with a view to the elimination of waste by unification of method, so far economic considerations have not been applied so extensively to scientific and technological research.

In Great Britain considerable attention has been given to the organisation of research, and large sums of money have been provided for its prosecution both by Government and private institutions and donors; but it has been neglected to organise the bibliographical research which should precede every experimental investigation. The failure to study this problem from the economic point of view is the cause of more inefficiency than is generally realised, and the application of simple economic laws would lead to a corresponding gain.

The precise extent to which research workers are wasting energy in repeating experiments that have already been made is difficult to estimate; but those who have given much attention to the study of the literature of their special subjects are aware that the proportion of labour which is wasted for lack of information on previous work is very high. It is indeed more than possible that half the energy expended in experimental research is dissipated in useless repetition. Perhaps it is less well perceived that the same proportion of useful work is published only to be buried out of sight in masses of volumes on the library shelves. To end this extravagance would increase enormously the efficiency of scientific research and the resulting stimulus to industry would be incalculable. It is worth while, therefore, that attention should be concentrated on the indexing of recorded information, so that hard-won data may be found at need and play their part as a basis for further progress.

A contribution to the solution of this problem was made at the Oxford conference of the Association of Special Libraries and Information Bureaux (ASLIB).[1] In the first place, it was suggested that

[1] The Association of Special Libraries and Information Bureaux. Report of Proceedings of the Fifth Conference held at New College, Oxford, September 14-15, 1928. (London: ASLIB, 26 Bedford Square, W.C.1.)

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a record must be kept of every useful scientific fact discovered, that is, every important publication in which scientific or technological research is recorded, in whatever language, should be filed in a library from which the books may be borrowed as required; and secondly, that every useful paper should be indexed.

When we consider what the second proposition involves, the figures are somewhat startling, but in attempting to measure research on a world scale, the million becomes the unit, as in rationalisation generally. Careful estimates show that each year more than a million useful scientific and technological articles are published, besides some thirteen thousand separate books on these subjects. At the same time, the energy of would-be bibliographers is so great that a comparable number of bibliographical entries are printed. This means that to index the total output of scientific and technical literature needs merely the co-ordination of the work of those who are now working independently making separate bibliographies, which are of limited value in the aggregate, on account of diversity of style and lack of method.

Thus the first step towards the production of a comprehensive index to recorded data is the co-ordination of bibliographical work by the standardisation of method; and this can be done by the universal adoption of a single classification. It is suggested that individual bibliographers should agree to work together for the common good by using the same system. By so doing, each one would get a classification that embodies the accumulated experience of his co-workers, while his work would be made available for use by all and theirs by him. It is granted that a standard classification is required for the production of a great bibliography, such as the International Catalogue of Scientific Literature, for example. Conversely, if a large number of bibliographical undertakings and individuals should agree to use the same classification, their total bibliographical output would be unified immediately. An individual worker or institution would then be able to collect references on a special subject from all the standardised sources, and intercalate them in one series in a single special bibliography; while very large libraries could form comprehensive indexes in which all such uniform entries would fall into place automatically, so that information needed could be found in a moment, with the saving of weeks or months of work at each consultation. Thus, by adopting a standard classification, the separate index entries, prepared by each individual, would fit into a single whole like the standardised parts of a machine; and, as the total volume of bibliographical work is so great, the desired index to knowledge would be well on the way to achievement.

The scheme above outlined depends on the provision of a suitable classification, such as the Brussels extension of the Dewey decimal classification. At the ASLIB conference there appeared to be some confusion of thought between the Brussels extension and the original Dewey decimal classification. Considerable support to the proposed scheme was apparent in the discussion, though unfortunately one of the more helpful contributions seems to have been omitted from the report. On the other hand, there was a tendency to discuss the limitations of Dewey's scheme, or of other systems, rather than to point out any defects in that which was advocated, or to suggest an alternative to it. It was remarked, for example, that "The problem merged into that controversial question of the general librarian, 'classified' catalogue versus 'dictionary' catalogue," although, obviously, a dictionary system, in which each classifier chose his own subject headings, could not serve to co-ordinate the work of an army of bibliographers throughout the world. The same speaker observed that "librarians of general libraries did want something better than the present basic Dewey, if we were to avoid making individual adaptations." Another urged that the Library of Congress had rejected the Dewey code. Actually, of course, by virtue of its auxiliary signs and tables, and extended schedules, the Brussels classification is more comprehensive than the original Dewey scheme, although comprised within a single volume not a great deal larger than that of Dewey. Apparently no one ventured to suggest that the Library of Congress classification could be used as the basis of a comprehensive index.

As another speaker suggested, "The best line of action in standardisation was to take what had already been done and see where the general consensus of opinion lay. . . . We should see which method had been most universally applied and adhere to that one." If these considerations are to be the basis of the decision, then it would seem that the Brussels classification would be chosen. We believe the system has been used for classifying all kinds of literature on the largest scale for a quarter of a century, and by many scientific and business institutions in all parts of the world.

It seems clear, therefore, that an attempt should be made to unify bibliographical work in the way suggested, with the view of providing a comprehensive index to the world's work and so preventing

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much of the wasted effort that now occurs. A good example has been set by the Optical Society, which prints with each part of its *Transactions* an index slip in which each entry bears the Brussels classification number at its top right-hand corner; and the Royal Photographic Society has added the classification numbers to *Photographic Abstracts*. Such entries can be cut up, mounted on cards, and intercalated in one series with all other bibliographical notices classified on the same system. Authors who contribute papers to such a society have the satisfaction of knowing that their work is indexed automatically in libraries where bibliographical notices are filed on the Brussels system, and is thus made available for all time whenever and by whomsoever it may be needed.

The X-Ray Microscope.

An Introduction to Crystal Analysis. By Sir William Bragg. Pp. vii + 168 + 8 plates. (London: G. Bell and Sons, Ltd., 1928.) 12*s.* net.

A NEW book from the pen of Sir William Bragg is always a noteworthy event. Before we open it we know that it is one which we have to read and one which it will be a joy to read. The latest is no exception. Based on and expanded from a series of lectures delivered at University College, Aberystwyth, it is intended, as its title implies, to introduce the general scientific reader to the method of the X-ray analysis of crystals. This method is no longer the monopoly of pure research laboratories, but is finding its way into the fields of applied science and is throwing light on many industrial processes. For this reason, if for no other, it is becoming more and more important that the scientific worker, no matter what his specialist line may be, should have a clear understanding of the principles of the method and some idea as to the possibilities of its application. Only so will he be able to gauge whether it has any aid to offer him in his own especial province. It is to such workers that this book is addressed, and that it will fulfil its purpose is beyond doubt. It is surprising how many aspects of the subject have been discussed in so small a volume, but the material is presented so clearly and with such skill that there is no sense of overcrowding.

The first chapter is devoted to an explanation of how the combination of the X-rays and the regular atomic arrangements characterising the crystal give rise to diffraction effects the interpretation of which afford an insight into the nature and details of these arrangements. Sir William Bragg then proceeds to explain the various experimental methods at present in use. In this connexion his treatment of the method of the rotating crystal is peculiarly attractive, and those readers who have read other accounts will appreciate its directness and simplicity.

Having laid down the principles and given an account of the actual experimental procedure, the author goes on to describe the results obtained by their application to some inorganic substances. Each example is carefully chosen so as to bring out some aspect of importance and emphasise some line of argument. These relatively simple examples serve to illustrate the main characteristics of the various crystal arrangements and to lead naturally to the next section, which deals with more general considerations developed by the older crystallographers, in particular with the theory of space groups. Federov and, independently, other workers showed that there is only a limited number of possible arrangements of atoms and groups of atoms, 230 in all. This classification had little save a theoretical interest until the advent of X-ray methods. The older crystallographer, dependent as he was on the observation of external features, could place his crystal in one or other of 32 classes, but he knew that it should be possible to make the division a finer one and choose from 230 space groups the one to which his substance belonged. Sir William Bragg shows us how these groups naturally arise, and, further, how and why X-rays can differentiate between them. No one who has studied the subject can fail to appreciate what a triumph of exposition this chapter represents.

The next chapter returns to more practical applications, and here we find a description of some work on rather more complicated substances which have been studied of recent years. The full interpretation of the X-ray results in these cases presents many difficulties, but this account shows us that steady progress is being made and that we are learning, step by step, to read the message conveyed by these diffraction patterns. The incompleteness of the solutions is not due to any inherent weakness of the method, but rather to our comparative inexperience in handling it.

In the final chapter we are brought back again to the study of simpler structures, those of the metals, in order that other and more immediately practical aspects of the work may be presented. The X-ray method is peculiarly suitable for the study of the different phases of alloy systems and for the investigation of the changes in the structure of a metal when it undergoes any cold working process such as drawing or rolling. Those who have to deal with such problems have not been slow to realise the

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