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Discovery and Invention

THE importance of scientific research in the modern State no less than in industry encourages discussions from time to time as to the mechanism of discovery and the best means of encouraging it. Dr. Lampitt, for example, in a recent address on fundamental problems of the food industry, stressed the importance even in industrial research of a true spirit of inquiry, the lack of which was liable to lead to unsound work which later investigators would invalidate. In stressing the importance of the spirit in which problems are faced he had in mind chiefly, however, the importance of a critical attitude towards experimental methods and published results ; he uttered a much needed warning against the tendency to assume the validity of such results and the adequacy of an experimental technique without any rigorous verification of its suitability for the particular purpose in mind.

It is unfortunately true that the critical spirit is not so general a characteristic of the young research worker, whether in industry or in academic work, as is desirable, but this is only one indication that scientific training sometimes fails to impart the scientific spirit or the secret of scientific method. A discussion recently held by the Institution of Mechanical Engineers starting from a group of papers on invention and the inventor, made a valuable contribution in this field by its attempt to elucidate the mental characteristics of the successful inventor—an attempt in which we have made singularly little progress since the days of Francis Bacon.

Some of the chief inventions upon which modern industrial development is founded, such as the steam engine, the power loom, printing and gunpowder, were all made by persons working independently of scientific research. It is true that the discoveries of science enlarged the bounds of invention and opened up much more fruitful fields for the inventor, but the technique, like the motive of discovery, differs essentially from that of invention. This is so widely true that the adequacy of invention as a basis of industrial progress is questioned by some shrewd observers, who look instead to the much wider use of scientific methods in the acquisition and application of new knowledge.

It is interesting, in this connexion, to note that Dr. Lampitt attributed the unsatisfactory position of our knowledge of food problems partly to the

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use of hit or miss methods. Such methods have occasionally been successful, as witness Charles Goodyear's discovery, after ten years of such haphazard work, that sulphur was the agent necessary to effect vulcanisation. They are too prodigal of time and money to be applicable under the team work conditions prevalent in modern industry, and the firm or industry which clings to them is destined speedily to be outstripped by its competitors.

Without providing us with a full philosophy of discovery, the discussion to which we refer, although relating mainly to invention, is highly suggestive in material from which such a philosophy might be evolved, or at least in stressing factors to be cultivated in the training of those undertaking a career of scientific research. The importance of accurate observation and experimental ability need no further discussion. They have been accepted since Galileo's day as the basis of scientific research, and Bacon's exposition of the possibilities of the scientific method assumed their use in the formulation and verification of hypothesis.

The importance of an accurate knowledge of the present position as a starting-point if duplication of effort is to be avoided should be obvious, but the importance of sifting that knowledge is often missed, as is the danger of paralysing initiative through excessive knowledge of detail. At this point our modern examination system exercises some of its most baneful effects. Only a clear understanding of what is involved in the scientific method, and a firm grasp of its essential principles, can enable the young investigator to-day to find his way through the literature bearing on his problem and avoid alike the mortification of merely repeating some previous work and the deterring or deadening influence of massed knowledge. Creative science is as dependent as creative art upon a sense of values, and upon intuition linked to imagination.

The further suggestion was made that youth is an important factor in creative work. By this we must understand the resilience and alertness of mind which are characteristic of those between twenty-five and forty years of age, but by no means their monopoly. Beyond that age, maturity of judgment and experience tend to be offset by habits of conservatism and complacency, not to mention the bondage of the preconceived idea from which comparatively few are able to free themselves. So far as science is concerned, however, rash is he who attempts to fix an age limit beyond which brilliant discovery and creative thought are rare and unexpected. On the contrary, Bavink pointed out quite recently that the really important discoveries in modern science are mainly the work of those who have long been at a position of eminence in their chosen field.

If the charge of 'grooviness' or lack of receptivity can rarely be brought against the real leaders of scientific thought, the important contributions which have come from those outside the industry in which the discovery or invention finds scope is a significant reminder of the value and inspiration which a fresh outlook may possess. This is true not merely of scientific discovery but of invention also. Benjamin Huntsman was a clockmaker whose desire for better steel for his springs constrained him to invent crucible steel. Henry Gort was a navy agent when he invented the puddling process for wrought iron; and Arkwright was a barber before he applied himself to the problems of spinning.

To the influence of professional organisations which may at times impede progress we have recently referred, but there are other personal qualities which are important. The ability to utilise the literature without being suppressed by it is largely dependent on a capacity for assimilation which in genius is often limited to a narrow field. The born organic chemist may be almost unteachable as regards mathematics, and a mechanical genius may find electricity a sealed book.

The place of initiative in the make-up of the investigator has already been emphasised. The capacity for concentrated effort is another important factor, and while a capacity for taking infinite pains does not constitute genius, genius is rarely without that capacity, at least in directions which serve its ends. Moreover, this capacity for concentrated effort is closely related to that desire to see the work executed in the most thorough and efficient way which is an essential part of the scientific spirit.

There are many other qualities which are to be found or desired in the scientific investigator and which condition his success whether in industrial or in purely scientific work. In both, the capacity for co-operation is of growing importance. Both classes are required, though in varying degree, to cooperate with other workers, sometimes in different branches of science, in an attack on a 'common objective'. Both are sometimes concerned with

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enlisting the interest and support of those possessing merely traditional or practical knowledge ; and both are also interested in the wider dissemination of the new knowledge, particularly in our technical schools.

To get a more scientific basis into industry, particularly our traditional industry, involves close co-operation between the man of life-long experience and the scientific worker. Such co-operation has a cumulative effect. It does far more than merely assist in the conduct of the industry on scientific lines, the solution of fundamental problems or the reconciliation of art and industrial practice and craftsmanship. The new problems it throws up provide a continual and invaluable stimulus to the scientific worker, which of itself is likely to yield rich fruit in the creative work which it incites.

Röntgen, and the Discovery of X-Rays

Wilhelm Conrad Röntgen : and the Early History of the Roentgen Rays. By Otto Glasser. With a Chapter : *Personal Reminiscences of W. C. Röntgen,* by Margaret Boveri. Pp. xii + 494. (London : John Bale, Sons, and Danielsson, Ltd., 1933.) 32*s.* 6*d.* net.

LOOKING backward we can see very clearly the monumental character of the discovery of the X-rays by Wilhelm Conrad Röntgen in November 1895. This was truly the beginning of the 'new physics' and the first of a series of profound and basic revelations, which even now show no sign of ending. It is given to few men of science to make discoveries which attract world-wide and lasting attention, but the X-rays with their amazing penetrating powers, and their immediate and beneficent application in medicine, made an appeal to men of science and laymen alike, which is not likely to be surpassed in our time. Röntgen's discovery in fact, as Sir J. J. Thomson remarked in his Rede lecture on July 10, 1896, "appealed to the strongest of all human attributes, namely, curiosity".

The recent publication of a biography of Röntgen by Dr. Otto Glasser is a timely reminder of very stirring days. At the period of his discovery, Prof. Röntgen was in his fiftieth year, and held the position of director of the Physical Institute of the University of Würzburg. He was born at Lennep in the German Rhineland, but his early youth was largely spent in Holland, to which country his parents emigrated when he, an only child, was three years old. He had a chequered school life at Utrecht, which ended in his taking up at the age of twenty years the study of mechanical engineering at the Zurich Polytechnic School. Three years later he obtained his Ph.D. and was appointed assistant to Kundt, who had succeeded Clausius in the chair of physics at Zurich. Kundt's friendship helped to settle Röntgen's future career for him, and he accompanied Kundt when the latter was called to Würzburg and afterwards to Strassburg. At the age of thirty-four years, Röntgen was appointed professor of physics at Giessen, and nine years later (in 1888) succeeded Kohlrausch at Würzburg.

Röntgen's interests were spread over a wide range of physics, though most of his published papers dealt with heat and general physics. He devoted, however, considerable attention to pyro- and piezo-electrical effects in crystals, and in 1888 he conducted important fundamental investigations which established the magnetic effects resulting from the motion of a dielectric between two electrically charged condenser plates. Röntgen's outlook on physics was thoroughly classical and his natural bent for exact experimental work, which had been strengthened by the influence of Clausius, remained with him all his days. He made little use of mathematics, but got his results with ingenious and simple equipment much of which he constructed himself. He greatly appreciated an ability to improvise apparatus, and held the view that a man should be able to make everything really necessary with a pocket knife. It is, therefore, not surprising that he normally dispensed with the services of an assistant and preferred to make his own observations.

Röntgen had been at Würzburg some five years when, in the early part of 1893, Helmholtz (then president of the Reichsanstalt) in a remarkable paper published in *Wiedemanns Annalen* in 1893, predicted the properties of electromagnetic waves of various lengths, and *inter alia* forecast a high penetrating ability and small refrangibility for waves of atomic dimensions. There is no evidence, however, that Röntgen was influenced by this paper when in October 1895 he decided to make some experiments with cathode rays. Rather would it appear that he was attracted by the contemporary work of Hertz and Lenard on electrical discharges in evacuated tubes. Following Lenard's practice, Röntgen completely enclosed the discharge tube within black paper. The room was darkened and Röntgen, who was working alone

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