the distribution of each different kind of molecules in the vessel is determined by the forces which act on them in the same way as if no other molecules were present. This agrees with Dalton's doctrine of the distribution of mixed gases.

J. CLERK-MAXWELL

ORIGINAL RESEARCH AS A MEANS OF EDUCATION*

THE subject of the value of original scientific investigation may be considered from many points of view. Of these, that of the national importance of original research is the one which naturally first engages attention; and it does not take long to convince us that almost every great material advance in modern civilisation is due, not to the occurrence of haphazard or fortuitous circumstances, but to the long-continued and disinterested efforts of some man of science. Nor do I need to quote many examples to show us the immediate dependence of the national well-being and progress upon scientific discoveries thus patiently and quietly made. If it had not been for Black's researches on the latent heat of steam, James Watt's great discovery, which has revolutionised the world, would not have been made. Practical applications cannot be made until the scientific facts or principles upon which those applications rest have been discovered. In our own science I might instance hundreds of cases in which discoveries made in the pure spirit of scientific inquiry have (generally in the hands of others than the original investigators) led to results of the first importance to civilisation. Chloroform was first prepared by Liebig in 1834; but it was Simpson who long afterwards applied it to the relief of suffering humanity. Faraday in 1825 discovered benzole, and from it Zinin prepared a substance called aniline, which for many years remained a chemical curiosity only interesting to the scientific man. In due course, however, a practical sphere of usefulness was to be opened out for this little known substance. Perkin discovered that this rare body was capable of yielding splendid colours. Commercial skill then at once seized upon aniline, and, instead of its being made by the ounce, it is now manufactured by thousands of tons, and the bright and beautiful colours which it yields are known all the world over, and are alike pleasing to the eye of the connoisseur of fashion and of the dusky denizen of the forest primæval. Thus, too, the purely scientific researches of our distinguished fellow-citizen Dr. Schunck, respecting the dyeing principle contained in the well-known madder root, laid the foundations for the subsequent discovery, by Graebe and Lieberman, of the artificial production of this naturally occurring principle, termed alizarine, the manufacture of which is now assuming such gigantic proportions. Again, the discovery of chlorine by Scheele, in 1774, lies at the foundation of the whole of our Lancashire trade, for without bleaching powder the cotton and paper manufactures could not exist on their present extended scale. I might almost indefinitely extend this list of discoveries, which, when first made, were apparently far removed from any useful application, but which all at once become the starting-point of a new branch of industry, and a source of benefit or gratification to mankind.

This subject of the national importance of original research is one which is gradually but surely forcing itself on public attention. A few years ago national elementary education was looked upon as a chimera; now it has become the question of the day. As soon as English people see as clearly as we do the imperious necessity for encouraging, stimulating, and upholding original research as containing the seeds of our future position as a nation, they will not be behindhand in securing the free growth of those seeds. It is therefore the bounden duty of all those whose employment or disposition has led them to feel the truth of this great principle, to leave no stone unturned to make widely known and keenly felt the importance of the national encouragement of original investigation.

It might have been a useful task for me to contrast what is done in other countries for the encouragement of free inquiry and research, and what is done, or rather left undone, in England. We should have seen that on the Continent of Europe, to a great extent, and in the United States, in some measure, those who have to wield the sceptre of government are not only aware of the national importance of original research, but, what is more, that they act up to their convictions, whilst we feel that the same cannot be said in our country. We should have seen that in Germany the facilities given in the universities, which are Government institutions, and in the other numerous and well-organised scientific educational establishments, to original research are very great; that an original investigation in some branch of human knowledge is considered the usual termination of the student's university career; and that degrees are generally given only when some new observations or experiments have been added to the mass of human knowledge. We should find that the position of professor is mainly influenced by the amount and quality of his original researches, and that this power, and not any secondary or subsidiary ones, as is sometimes the case with us, is taken as the proof of a man's fitness to fill the professorial chair.

It is my wish, however engrossing this view of the subject may be, to ask you to consider to-day another aspect of the question--viz. the educational value of original research; the value of personal communication with nature for its own sake, the influence which such employment exerts on the mind, the effect which such studies produce as fitting men for the active duties of life, and the question, therefore, as to how far original investigation should be encouraged as an instrument of intellectual progress. It may be well, however, before we commence this special question, to place clearly before our minds what is meant by scientific inquiry in general, and to see how it is related to the studies and habits of mind with which men up to the dawn of the present, or scientific age, have been familiar.

In the first place, then, the essence of the scientific spirit is that it is free and disinterested. If, therefore, any of the habits of mind, studies, or beliefs in which men have hitherto indulged have not been free nor disinterested, in so far they have not been scientific. In the second place, the spirit of true scientific inquiry knows nothing of tradition or authority. It lays down laws for itself, and refuses to be bound by any others. Scientific education begins with no preconceived idea in accordance with which everything else must be moulded. It starts in simple communion with Nature, and is content to pick up little by little the truth which she is always ready to communicate to patient listeners. Thus step by step and generation by generation, slowly but surely, the perfect edifice of science is being built up, and all those who contribute, however insignificantly, to this great work have the safe assurance that their labour has not been in vain. This process is, it is clear, at once opposed to, and, if successfully carried out, subversive of the old order of things. Between a system based on authority and one founded on freedom of thought and opinion there can never be any united action; and whilst fully acknowledging that intellectual eminence, and, of course, moral excellence, are common to all classes of men, and are not confined to those holding particular opinions, if only they be honest, it is as well that we should admit with equal candour that the followers of the old system have no claim to be called scientific, and that there is, from the nature of things, a great and impassable gulf between us and them.

It does not concern us at present to inquire which of these two systems, the free or the authoritative, is for the future to rule the world. It must now suffice for us to see clearly that the habits of mind necessary for the establishment of the one are absolutely opposed to those needed for the success of the other.

I must, however, here not be misunderstood. It would ill become me, connected as I am with a college to which it has been our constant aim to impart a university character, to undervalue or depreciate the study of subjects other than those included under the head of the physical sciences. Literary studies, whether of modern or ancient authors, giving an acquaintance with the noblest thoughts and opinions of the great men of past ages; historical studies, giving us a knowledge of the acts of men in times gone by; the study of language and philology, as giving a knowledge of how men of all times and countries express their ideas and language; of logic, as pointing out the laws of thought; and above all, that of mathematics, are all matters of the highest importance, the neglect of which would render our education poor and incomplete indeed. The same rules, however, which all acknowledge to be necessary for the teaching of physical science must be applied to the study of all these subjects. In short, the *scientific method* must be employed in all cases and carried out to its fullest extent. Whilst attempts to shackle the mind, or to stifle free inquiry, which have too frequently succeeded in past times, and which may, if we are not on our guard, succeed again, must be repulsed with all our vigour.

* Address by Prof. Roscoe at the opening of the new buildings of the Owens College Manchester.

I would, however, here wish to protest against the supposed materialistic tendency of scientific studies. It is true that certain opinions and professions of belief have been and will be shaken by studying the book of nature; it is also equally true that the study of nature does not and cannot interfere with the highest and noblest aspirations of the mind of man. In the investigations of every branch of science we come at last to a point at which further inquiry becomes impossible, and we are obliged to acknowledge our powerlessness and insignificance. We can see and learn concerning only the minutest fraction of the great whole of nature, and it is with this minute fraction alone that we as men of science are concerned.

In inaugurating, as we are now doing, a scientific department of an institution devoted to the higher education, it may be well to glance for a moment at the preliminary stages through which, in the subject of chemical science, with which alone I am competent to deal, a student must pass to reach the portal of original inquiry. And first let me gratefully acknowledge the help which we have received in endeavouring to find a habitation for a school of chemistry aspiring to be worthy of the intellectual vigour and manufacturing power of the great district of which this city is the centre—help not only of the necessary, and therefore valuable kind of pecuniary assistance generously and willingly given, but help of a personal, and therefore still more valuable kind, without which the funds would have been useless, and our scheme for the foundation of a really great scientific institution would have fallen to the ground. The results of this help you now see in this large theatre, and in the splendidly fitted laboratories behind it. They are, I say it with confidence, the most spacious and best arranged laboratories in Great Britain, and will be found, I believe, second to none in the world for convenience and suitability to their proposed uses. It now remains for my colleagues and myself to discharge our debt; to show that the confidence which has been placed in us has not been misplaced, and to prove year by year that the goods we furnish in the shape of soundly and scientifically educated chemists bring a return worthy of the capital, both in specie and intellect, which has been expended upon their production.

Our mode of instruction in the principles of chemistry is of two distinct kinds: (1), by lectures, accompanied by experimental illustration by the lecturers, as well as by recapitulatory and tutorial classes; and (2), by experimental work practically carried out by the student himself in the laboratory. Both of these means of obtaining command over the facts and principles of our science should be carried on simultaneously; the lectures serve as giving a general view of the main features of the subject; the laboratory work brings the student into direct contact with Nature, and gives him an insight into her processes, which can only thus be obtained. In the lecture room the student forms an idea, as in a panorama, of the general appearance of the country; but it is in the laboratory, as in a walk through a given district, that he first learns what the land he is travelling through is really like. And although we know that we must spend much time and labour if we go on foot, we know that we shall be rewarded by a vivid and lasting impression, and one which may perhaps give a new colour to our lives. It is thus with the study of chemistry; the laboratory is the place where the details of the science are really mastered; and a young man must not expect to become a competent chemist without having passed several years of hard and unremitting toil in solving the sometimes tedious and difficult problems which are presented to him.

It is not necessary for me here to detail to you the particulars of the course of instruction which all students of chemistry, as a rule, go through. Suffice it to say that this course begins at the very A B C of our subject; and, if I am freely to speak my mind, I would say that in general I do not object to take students who know nothing of the science. We first seek to give him some notion of the kind of phenomena with which the science is concerned; we then begin to train him in manipulative dexterity, and, by a graduated series of examples and exercises, make him acquainted with the fixed and exact quantitative laws upon which our science is founded. From the beginning we introduce a strict system of note-taking and of carrying out simple chemical calculations, so as to insure a firm foundation for the subsequent building. The student then begins to learn the properties of the more commonly occurring amongst the sixty-three elementary bodies of which (as far as we are yet aware) the material world is built up, and properties of their compounds. He commences the study of qualitative analysis, and at last he is able to tell you the nature of the exact constituents of any substance, whether of earth, of air, or of sea, of mineral, vegetable, or animal nature, which you may ask him to examine. He has accomplished a great work, and if he has carried his examinations as far as the reactions of the rare elements (as is usually the case with all our students), he is master of the first or qualitative stage of the science. Next the question arises as to the quantity of each constituent present in the given substance, and the second or quantitative stage is reached. This is necessarily a longer and more difficult matter than his preceding task. Not only must the choice of methods of separation and estimation be successful, so as to employ good ones and eschew the bad or inaccurate ones, but skill in manipulation must be forthcoming. All depends on accuracy and care in performing delicate operations, such as weighing, collecting and washing precipitates, and a hundred other manipulations, and the results of many days' work may be in a moment lost by one false step or one careless action.

In all this preliminary work the hand is gradually trained to perform the various mechanical operations, the eye is at the same time taught to observe with care, and the mind to draw the logical inferences from the observed phenomena. Habits of independent thought and ideas of free inquiry are thus at once inculcated; no authority besides that of the senses is appealed to, and no preconceived notions have to be obeyed; the student creates for himself his own material for observation, and draws his own conclusion therefrom. If he is inaccurate either in his manipulation, his observations, or in his conclusion, nature soon finds him out. Something or other is out of order, and he is sent back with the task of finding out his mistake for himself. Not until all this has been accomplished (and very often not then) is the student fit to think about original research. Before he can successfully grapple with new difficulties he must have learned to overcome the old ones. His hand must be dexterous and accustomed to meet all the mechanical difficulties which invariably accompany such investigations; his eye must not only be open to what he expects to see, but, what is far more difficult, it must quickly seize upon the occurrence of phenomena which he does *not* expect to see; his mind, working, perhaps, with a leading thought—for without this, original work is almost impossible—must be free in its power to grasp any new combination of ideas to which the phenomena may suddenly and unexpectually give rise, and be willing at once to relinquish a favourite and cherished hypothesis if the results of experiment prove that hypothesis to be erroneous. This dexterity of hand, quickness and keenness of sight, and pliability of mind must in greater or lesser degree be possessed by all who would undertake original scientific work. I do not mention as a preliminary necessity a competent theoretical knowledge of the phenomena and laws of our science, because, though this is a matter of course, many having this knowledge will altogether fail, owing to their not possessing the other requisites.

In carrying out, then, even the simplest original investigation, some or all of these requirements are needed. In addition, other faculties are called into play by the very fact of the phenomena being in part at least new. Not only do we ourselves not know what to expect, but nobody can tell us what will happen. We are exploring new country, and our outlook must therefore be doubly sharp; we must be prepared for every possible event, and ready to meet every change of fortune. We must, like a traveller, not be discouraged by reverses, but patiently persevere in our course, feeling convinced that the path, which for a long time may be a thorny one, must in due course lead us to a point from which we shall enjoy an extended view of the surrounding country, and be able to trace the tortuous paths by which the elevation was reached. The faculties which are called into active operation in the prosecution of experimental scientific research are, in fact, exactly those which are valuable in the every-day occurrences of life, the proper employment of which leads to success in whatever channel they may happen to be directed. A man who has learnt how successfully to meet the difficulties and overcome the obstacles which occur in every experimental investigation, is able to grapple with difficulties and obstacles of a similar character with which he comes in contact in after-life.

(*To be continued.*)