many years afterwards serious students of chemistry and some other branches of science resorted to the German universities for the instruction which they could not obtain in their own country in the higher parts of their subjects and in research, usually returning with the Ph.D. degree. In London the only chemical laboratories for the reception of students were at the Pharmaceutical Society (opened in 1844), at the Royal College of Chemistry (opened in 1845), at University College, at King's College, and at the Royal School of Mines in Jermyn Street. But a great step forward was taken when in 1860 the University of London founded for the first time in England a Faculty of Science and began to hold examinations for the degrees of Bachelor and Doctor in that faculty. The effect was immediate and extensive. The programme put forth appeared formidable, but it provided at once a stimulus and a guide to all the numerous casual students scattered throughout the kingdom, some attending classes of the Science and Art Department or mechanics' institutes, some engaged privately in evening study after business. As a simple matter of autobiography, my case was one of the latter kind. I was then a young demonstrator in the laboratory of the Pharmaceutical Society, but I was fairly well up in the physics and chemistry of that day. I also held a Science and Art certificate as a teacher of botany. The matriculation was the chief obstacle, as I had practically learned no Greek at school. This, however, diligence enabled me to surmount, and by 1868 I got my B.Sc. with First Class Honours in chemistry.

My case must have been very similar to that of dozens of young men at that time to whom came the opportunity of getting a stamp or brand without the necessity of throwing up the occupation by which they were getting a living. But it did more than that, for the syllabus of subjects comprised the whole circle of the sciences, including, besides the various departments of natural and experimental science, logic and moral philosophy, so that candidates were required to show at least a rudimentary knowledge of the subject-matter of various branches of human knowledge of which they would otherwise have remained totally ignorant. My own experience leads me to think that this "little knowledge," which, according to Pope's mistaken aphorism, is "a dangerous thing," is of great value even to the specialist. A *Doctor*

of Science ought, and is supposed, to be an expert in some direction or other, but not long ago I met a London D.Sc. who had never heard of Bishop Berkeley. This curious fact revealed a state of ignorance of all philosophy and much more which he would have escaped had the old regulations been retained. This is, of course, now past praying for, and research, which implies specialism, is the order of the day. It is only consolatory to reflect that anything which induces concentrated thought has an educative effect on the young mind.

One of the greatest movements for the promotion of education in general, and conspicuously in the encouragement given to scientific teaching and research, was the foundation of the university colleges and new universities distributed over the country. In Manchester the college which became the nucleus of the present Victoria University had been founded by John Owens in 1851, while in London University College (the original University of London), King's College, and Bedford College were already in existence. But in 1871 the first step was taken towards the extension of similar benefits to other parts of the country. In the first instance these institutions subsisted on endowments provided by private benefactors, supplemented by aid from local subscribers or such bodies as the Guilds of London. But in a very few years these were found to be insufficient, and serious financial embarrassment had to be faced. After repeated applications to the Government for assistance, and a long struggle, the battle was won, and in 1889 State aid was granted in the form of the very modest amount of 15,000*l.* per annum, to be divided among the English colleges. Sir William Ramsay was one of the most active promoters of the movement, and the full story is recorded in his "Life" (Macmillan).

As to the future of scientific discovery, who can tell? The wonders which have been successively revealed during the last fifty years should teach us not to be surprised at anything. Co-operation among workers and organisation may do something in the way of gathering up knowledge of Nature, but whatever is done by Governments, institutions, or individuals, one consideration should ever be kept in view, and that is that genius will find its own way, and it would be worse than useless to prescribe subjects, or methods, or opportunities to the man who has been gifted by the gods.

ASPECTS OF SCIENCE AT UNIVERSITIES.

BY DR. ALEX HILL.

DOUBTLESS the provision made by the universities of the United Kingdom for the teaching of science and for research is still inadequate. It always will be. The occupation of the field and its extension is a single process, not a process and its result; since the farther man explores, the wider is his vision of the unexplored.

NO. 2610, VOL. 104.]

The improvement which has marked the past fifty years is roughly proportionate to the growth of knowledge and to the investigator's success in utilising it for the meeting of human needs.

Oxford, Cambridge, the four Scottish universities, Trinity College, Dublin, Durham (with no Newcastle College of Science), and London were

the only universities in 1869. To these must be added Owens College, still in the house in Quay Street "to which a chemical laboratory and a large lecture-room had been added." In science Cambridge led the van with, possibly, University College, London, as her nearest rival. It is unsafe to adopt an order of merit. Much depends upon the point of view. Edinburgh, for example, in the biological aspect, might lay claim to precedence. We may take Cambridge and University College as examples of the provision made for science, then and now, seeing that space will not allow of a fuller treatment of the subject.

Science attained to the status of a department of knowledge when the Natural Sciences Tripos was established. The first examination was held in 1851. Yet for many years the various branches of natural science were regarded as possible substitutes for the humanities in the education of a gentleman, rather than as vehicles of a grim and strenuous discipline for the work of life. Science was Whewell's *forte*, omniscience his *foible*. The Tripos was reminiscent of his influence. All branches of science ranked alike. A candidate's place depended upon his aggregate of marks. To secure a first class he must show that his knowledge, like that of the stupendous Master of Trinity, ranged from zoology to mineralogy.

The institution of the Tripos was a powerful stimulus to scientific study. New buildings were erected in 1864 and 1865, yet the contrast between the accommodation and equipment of the various departments, in 1869 and to-day, is so marked as to be amusing. Salvin's building was a palace as compared with the hovel in the south-east corner of the old Botanic Garden, erected in 1786 by Mr. Bradwell, bricklayer, and Mr. Kaye, carpenter, both of Cambridge, in which, until 1864, all departments, with the exception of geology, had been lodged; a building which for several years after that date was shared by the professor of chemistry and the professor of anatomy (including comparative anatomy and comparative physiology). The lecture-room on the upper floor of this building was well lighted, but the metallurgical laboratory on the ground floor, and the cabinet in which, if possible, a body was dissected every year, were dark and inconvenient in such degree as seemed appropriate to the evil-smelling and repulsive rites to which they were devoted.

Salvin's building, which was enlarged later by the addition of an upper story, provided accommodation for mineralogy, botany, zoology, and natural philosophy. For long the block was known as the "New Museums," since the greater part of its space was given up to the housing of the herbarium and the collections of minerals and of zoological specimens. Museums, be it noted, were considered, in those days, as of far more importance than laboratories for the teaching of science. The geological collection was stored—it would be misleading to write "exhibited"—in Cockerell's building, now given up to the university library.

NO. 2610, VOL. 104]

To-day the whole of the old Botanic Garden, with much surrounding property from which houses have been cleared, together with about six acres on the opposite side of Downing Street, is covered with noble buildings. Fortunately, they are not too noble. For the most part, they look as if they were intended for the purposes for which they are used. Cambridge is happier than some modern universities in this respect. The dignity of science is not enhanced by Gothic or Palladian architecture. Science looks to the future, not to the past. Steel girders and sheets of glass can be rearranged to meet new needs. The cotton-mill style is the only style appropriate to museums and laboratories. Proportion, light, ventilation, and convenience of access of the building as a whole and of its several parts are the only merits for which the man who designs them can lay claim to renown.

Excluding the professors of mathematics and astronomy, the scientific staff of the university comprised the professors of chemistry, anatomy, botany, geology, natural philosophy, and zoology, each of whom received a yearly stipend of 300*l.*, together with a demonstrator of anatomy, who received 100*l.*, and an attendant at the chemical laboratory. These officers alone were paid out of the University Chest. Additional assistants, lecturers, and demonstrators were to be found in some departments, but their employment was the professor's private affair. To the university staff must be added a lecturer in natural science at Trinity, two lecturers at St. John's, a medical lecturer at Caius, the superintendent of the laboratory at Sidney, and two lecturers in medicine and natural science at Downing. To-day we find nineteen professors of natural science and seventy-three readers, lecturers, and demonstrators on the university staff, and forty-three college lecturers.

The lures set in the gates of science were scarce likely to beguile a student from the broader ways. "Three-quarters of all university prizes and more than one-half of all college prizes are awarded for classics and English," the Calendar boasted in 1869. English might as well have been omitted. It could not stand alone. The only prize for natural science was the Sedgwick. Thirteen names appeared in the Natural Sciences Tripos, against 111 in the Mathematical and 73 in the Classical class-lists. In 1914, 153 men and women took honours in the Natural Sciences Tripos, against 121 in the Mathematical, 113 in the Classical, and 352 in the various other Triposes which have come into existence in recent years.

At University College, London, the laboratory accommodation was singularly modest, as, indeed, it remained until quite recent times. The steady flow of discovery which has issued from the cramped, dark, inconvenient chemical laboratory is testimony to the genius of the men who have successively occupied the chair. Students were not expected, in 1869, to do practical work, as understood to-day. The writer recalls sitting in a row of other students, in 1872, pulling petals

from flowers and filling his notebook with floral diagrams; attending demonstrations in the physical laboratory; dissecting, when it came to his turn, a rabbit to be inspected by the class, whilst Prof. Grant, in the dress-coat, brocaded vest, and white cravat of the Georgian period, discoursed philosophy, with occasional reference to the rabbit. In the chemical laboratory students worked in relays, but so limited was its space that the lecture-theatre had to be fitted for the examination in practical chemistry by clamping a tray for each student on to the sloping board on which, during lectures, the notebooks rested. A similar description would apply to the laboratories at Edinburgh, Glasgow, Dublin.

Provision for teaching and research has kept step with the uses to which scientific knowledge has been turned. The distinction drawn between pure science and applied science is essentially unsound and wholly mischievous, as if the purity of

science were sullied whenever the problem to be solved is suggested by an immediate human need. The discoveries made by an investigator who has a practical application in view are as truly additions to the sum of human knowledge as those which reward a worker who is following a line of research which can never, so far as he is aware, contribute to man's comfort. In most cases the practical man also advances the grasp of pure science by directing attention to gaps in theory, and by asking the professors questions which they cannot answer. The universities have been slow in realising their duty to the crafts and manufactures. It is greatly to be hoped that, in the near future, we shall cease to hear of independent bodies set up for the purpose of carrying out either "scientific" or "industrial" research. There is but one Science, and the universities are the instruments for extending its range.

FIFTY YEARS OF TECHNICAL EDUCATION.

By J. H. REYNOLDS, M.Sc.

JUST fifty years ago there appeared a remarkable book, the fruit of much thought, experience, and wide travel, entitled "Systematic Technical Education for the English People." Its author was Mr. J. Scott Russell, F.R.S., the designer of the *Great Eastern*, the largest vessel of that time, which rendered singular service in the laying of the first Atlantic cable. The volume was dedicated to the Queen, and the purpose of the dedication was declared to be "to entreat her Majesty graciously to consider the case of the uneducated English folk who are now suffering great misfortune in their trade, commerce, and manufactures, as well as in their social, moral, and intellectual condition, through having been neglected and allowed to fall behind other nations better cared for by the men whose duty it was to lead as well as to govern the people." The Queen was urged "to issue her Most Gracious Majesty's commands to her Majesty's Ministers to see to it that for the future the dexterous, energetic, willing working people of England receive at the hands of the Government a practical education for useful life as thorough and systematic as the best-educated nation in Europe."

Mr. Scott Russell declared that the condition of English education, both general and scientific, compared very unfavourably with that prevailing in Continental countries, notably in Prussia, Saxony, Württemberg, and Switzerland, whilst no provision worthy of the name existed for technical education and training, which were abundantly provided for all grades of workers in industry and commerce in all the countries named. He called in evidence the lessons taught by the Great Exhibition of 1851, which owed its origin to the enlightened views of the Prince Consort,

and in which the civilised nations of Europe received their first lessons in technical education. Our superiority in machinery and its products was manifest, whilst in articles demanding beauty and grace of design we were plainly lamentably far behind some Continental nations. Mr. J. Scott Russell concludes his book by pleading for the appointment "of a powerful statesman to be Minister of Public Education with a strong will; a complete organised plan of a people's teaching; a determination that, at whatever cost, the English people shall become in one generation the best-educated nation in Europe—and it will be done." We have at last such a man in the present President of the Board of Education, and it is to be hoped that he may so remain and be given the means to carry out the essential reforms embodied in the great Act of 1918.

The enormous progress made by the several important nations as a result of the object-lesson of 1851 was made clearly evident at the exhibition held at Paris in 1855. England was no longer, in consequence of the establishment of schools of design and the circulation of the best models in the areas affected, outstripped in pottery and glass, whilst, on the other hand, foreign nations, such as France and Germany, recognising the advantage which England enjoyed in the possession of abundant raw material, such as coal, iron, and steel, together with skill in adapting them to the purposes of industry, and realising that the only effective way of meeting it was to apply higher science and research in their treatment and application, had already, with this aim in view, established schools for the education and training of both masters and workmen, with the result that their engineering exhibits made a remarkable display.