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.

The International Exhibition of 1862 held in London showed a further striking advance on the part of foreign nations: Switzerland with her aniline colours, Prussia with her ingots of Krupp steel, France with her steam-engines, and the United States with ingenious machinery for economising labour. But it was the Exhibition of 1867, held in Paris, which offered conclusive and disturbing evidence of the successful efforts of foreign nations in the application of organised scientific and technical education to manufactures, especially in the production of well-designed steam-engines, boilers, ships' armour, and artillery.

In the great ironworks at Creusot, in France, there was established a systematic organisation of technical schools such as could be found nowhere in England. It was the considered judgment of skilled observers and of representative workmen in various trades who visited the exhibition that England no longer held the pre-eminence in industry which was surely hers in 1851, due, as was declared, entirely to the absence of sufficient facilities of training in pure and applied science. The Science and Art Department, founded in its entirety in 1853, had encouraged the establishment of evening classes in science and art, but they reached only a fraction of the workers, and except in a few instances they had little bearing upon the technology of industry. It may safely be said that in 1869 out of 1,250,000 youths engaged in industry not more than 5 per cent. were receiving any training in applied science in the day and evening institutions of the kingdom.

The period of trade depression that followed after the year 1869 and the awakening of the nation to the serious industrial competition of certain foreign nations, largely due to better educational provision, notably of scientific education, especially for the leaders of industry, gave rise to earnest efforts to provide the means of scientific and technical training in this country. The Livery Companies of the City of London joined with the City in the creation of the City and Guilds of London Institute in 1879, the purpose of which it was to provide a day and evening technical college at Finsbury (opened in 1883) for boys purposing to enter upon industrial pursuits, together with a central college at South Kensington, opened in 1884, for the training of future industrial leaders and teachers of technology. In addition, the aim of the institute was to encourage the establishment of technological classes throughout the kingdom and to set up a system of examinations in the subjects. Large annual sums were subscribed in support of these objects, and certificates, prizes, and medals were awarded to successful students.

Considerable annual grants were given in aid of the establishment of technical schools in Manchester, Sheffield, and other places, and the Company of Clothworkers made itself responsible for the establishment and support of a textile department at the Yorkshire College, Leeds, whilst the Company of Drapers founded and supported the People's Palace, now the East London College. The interest aroused in the subject of technical education and the rising competition of Continental nations led the Government to appoint in July, 1881, a Royal Commission "to inquire into the instruction of the industrial classes of certain foreign countries in technical and other subjects for the purpose of comparison with that of the corresponding classes in this country, and into the influence of such instruction in manufacturing and other industries at home and abroad." The Commission presented in 1884 an exhaustive and highly informing and stimulating report after nearly three years' inquiry not only in Europe, but also in the United States, which had a profound effect upon public opinion, and led to the passing of the Technical Instruction Act of 1889, which empowered local authorities to rate themselves for the support of technical schools. This was followed by the Act of 1890, whereby nearly 800,000*l.* annually derived from the customs and excise duties was placed at the disposal of local authorities for purposes similar to those of the former Act.

This resulted in the establishment, chiefly by the local authorities, of technical schools and colleges throughout the kingdom, a few of which were effectively equipped and staffed for the training of qualified day students intended for leading positions in the various industries, and some of these schools, like those of certain London polytechnics, Manchester, Glasgow, Sheffield, Bristol, and Belfast, came into intimate relations with their respective universities. The Education Act of 1902, which placed all grades of education, exclusive of the university, under the control of the local authority, had a unifying effect which made it possible to correlate the various forms of education and to bring the opportunity of secondary and technical training within reach of the poor but capable scholar.

Meanwhile, many important industries, notably those producing scientific instruments, chemical ware, fine chemicals, and especially artificial dyestuffs, had passed largely into the hands of German and Swiss firms, as witness their exhibits in the Paris Exhibition of 1900, due entirely to the command on their part of an effective supply of efficient scientific workers, so that they held the "key" of our textile trades so far as printed and coloured goods were concerned. The course of the great war has made clear, however, the innate capacity and resource of the English manufacturer in these and other products of foreign origin, as well as in the fertility of his invention and in the success with which he has met and solved many technical problems arising during its course. Striking evidence of this was displayed in the exhibitions of British scientific products held in London and Manchester in 1918, and in London in 1919, under the auspices of the British Science Guild—an organisation established to further the cause of scientific and tech-

nical education and promote attention to scientific method in all national affairs.

Another fruit of the war is the awakened interest in the subject of education on the part of large employers, and especially of the importance of scientific training and research. A Committee of the Privy Council has been instituted for the purpose of encouraging scientific and industrial research, with numerous sub-committees dealing with various sections of industry and with special products. Ten research associations have been formed in respect of the chief industries, and twenty-eight important researches have been undertaken and aided from the fund of 1,000,000*l.* placed at the disposal of the Committee by Parliament.

The Education Act of 1918, which should be made operative without delay, will, when it comes into full effect, supply a far higher type of student for our arts and industries. As showing the advance within the last fifty years, there were at the beginning of that period only four universities which granted degrees in England and Wales, one of which (London) was merely an examining body. Now there are eleven duly incorporated, with numerous colleges attached to them, many of them chiefly concerned with technical training and education. These universities are all well equipped and staffed for the teaching of science and its applications, in the encouragement of which this journal has borne no small share since its foundation in 1869.

Yet we have still far to go if we would keep ourselves abreast of foreign educational enterprise. There were in 1914 twenty-one universities in Germany, with 68,000 students, against eighteen in the United Kingdom, with 27,000 students. There were also eleven technical high schools in Germany, and sixteen other special high schools for agriculture, mining, etc., with 21,000 students, as against 5000 in ours, and in both age and standard of education at entrance their students rank much higher than ours. The State grants to universities and colleges in the United Kingdom were about 500,000*l.*, in Germany nearly 2,000,000*l.*, and in the United States 7,000,000*l.*, but in addition there was given nearly 4,000,000*l.* in private benefactions, as compared with 200,000*l.* in the United Kingdom. To maintain our position as a leading nation in industry and commerce, we need to increase the potentiality of our manhood, to secure which will require a much larger expenditure of money and effort. We want accomplished leaders and a well-educated and highly trained rank and file.

THE PROMOTION OF RESEARCH.

By SIR RICHARD A. GREGORY.

The great inventions of former ages were made in countries where practical life, industry, and commerce were most advanced; but the great inventions of the last fifty years in chemistry and electricity and the science of heat have been made in the scientific laboratory: the former were stimulated by practical wants, the latter themselves produced new practical requirements, and created new spheres of labour, industry, and commerce.—J. T. MERZ.

THE recognition of the value of scientific research as a determining factor of progressive development has been a common note of many public utterances in recent years. Ministers and labour leaders, manufacturers and men of letters, are impressed with the results of experimental inquiry and do homage to those who devote their lives to it. Rarely, however, is the spirit which prompts most scientific investigations understood. "The quickening power of science, only he can know from whose soul it gushes free." It seeks not to use, but to know: its aim is not an engine of war or a profitable invention, but the discovery of new knowledge and the creation of new ideas for all mankind. Researches which have practical applications as their proximate or ultimate ends are not likely in these days to need much advocacy for their support, but those which have no such aims must, like virtue, carry their own reward with them. The standard of value to-day, more than ever it was, is worldly riches, and if all research had to be measured by it science might gain the whole world, but it would lose its own soul by so doing.

When the State or the manufacturer makes provision for research, tangible results are expected, and freedom to explore what, from a practical point of view, seem to be unpromising by-paths is discouraged. To a certain extent Mr. Gladstone was right when in 1872 he termed the intervention of the State as "interference" with science, calculated to discourage individual exertion and so obstruct discovery and progress. The view then taken was that the more science was left to itself the better for it. We are far from accepting this *laissez faire* principle entirely, but there is some truth in it so far as purely scientific research is concerned. Creative genius never has been, and never will be, willing to submit to bureaucratic control or industrial needs, yet it discovers the new lands in which rich fruits are afterwards cultivated for the benefit of the world. While, therefore, we acknowledge with much satisfaction the growing appreciation of research as a means of promoting industrial advance, we trust that the apparently useless and unpractical pursuits of purely scientific workers will be regarded as equally worthy of encouragement.

When the publication of NATURE was begun fifty years ago, experimental research received little or no support from the State. Astronomical work was carried on at the Royal Observatory, Greenwich, and natural history objects were displayed at the British Museum, but there was absolutely no provision in this country for the support of experimental investigation of a modern