The most important invention since Meisenbach's is the three-colour half-tone process. This was based upon James Clerk Maxwell's researches made so long ago as 1861. The drawing or object is photographed successively through three colour filters: for the red negative a green filter is used; for the blue, a red; and for the yellow, a violet or blue filter.

A half-tone block is made from each colour negative, an operation requiring the utmost accuracy to get register, and the screen is placed at different angles to get white into the interstices of the grain and to prevent an effect like that of "watered silk."

In all these processes intended for the letterpress machine, the metal plate, for rough work of zinc, and for more delicate work of copper, is mounted "type-high" in the manner described above.

A more recent invention obviates the use of the objectionable but necessary shiny coated paper: An impression is made from a half-tone plate upon an india-rubber roller and transferred to the paper, which may have an ordinary or even a slightly rough surface. Excellent work has been done with some subjects by the application of this method to the three-colour process, but so far the average results are not equal to those obtained by the use of blocks upon glossy paper. This is called "Off-set."

A very important photographic process, used until lately more on the Continent than in England, where it was first introduced in 1870, is collotype; or, as it was known in earlier days here, "heliotype." Mungo Ponton, in 1839, used bichromate of potassium, and Fox Talbot, in 1851, discovered the action of this chemical in making a gelatine film sensitive to light. When a negative is printed upon a film of gelatine so sensitised, it absorbs moisture in inverse ratio to the amount of light it has received, and when by means of a roller a greasy ink is applied to it, it takes the ink in the ratio of its dryness, and so gradation in the print is obtained. The advantage of this method of reproduction is that it is not necessary to use the glossy coated paper, which is essential if one is to obtain the best result from either a half-tone block in black or from a set printed in three colours. The disadvantage is that it cannot be printed on a letterpress machine in the same way as a block.

This process is unrivalled for facsimiles of documents and early manuscripts. But for the reproduction of pictures and illustrations requiring a greater depth of tone, photogravure remains without a rival at present. It is interesting to note that Niepce de Saint-Victor, in 1847, had produced a photogravure plate. He coated a copperplate with bitumen of Judea and exposed it to the action of the sun under a line engraving, which acted as a photographic positive, afterwards biting the protected lines into the copper, and etched a plate which could be printed on a copperplate press.

Since that time many modifications have been made, the more important being the process invented by Rousillon based upon a beautiful invention of Walter Bentley Woodbury, patented in 1866, and introduced by Messrs. Goupil, of Paris, early in the 'seventies, which was an electrotype from a gelatine mould in relief; and that by Klic, of Vienna, who invented the method now most generally used: A copperplate is covered with an aquatint ground made by dusting powdered resin or bitumen of Judea on it and then melting it with a gentle heat. This causes the particles to run together in little "hills," leaving minute "valleys" between them. Upon this plate an ordinary carbon positive made from a reversed negative is squeegeed down and developed. When it is dry it is placed in a bath of perchloride of iron. This acid bites through the gelatine of the carbon positive and into the copper, the depth being graduated by the varying thickness of the gelatine of the carbon positive. When the biting is completed the gelatine is cleaned off, the copperplate inked by filling the interstices or pits and the excess of ink wiped off, first with canvas and fine muslin, and, finally, with the printer's hand, and an impression taken upon damped paper in the same way as from a copperplate engraved by hand.

An adaptation of photogravure to machinery was made at Lancaster about twenty years ago. It consists in applying Klic's method to a copper cylinder by the use of a half-tone screen instead of a grain produced by bitumen or resin. After inking the surface of the cylinder it is wiped to remove the superfluous ink and impressions on paper are made by a rotary motion at a great rate. The process is now largely used for illustrations for weekly illustrated newspapers and magazines.

PROGRESS IN SCIENCE TEACHING.

BY SIR WILLIAM A. TILDEN, F.R.S.

A MAN who remembers clearly the first Great International Exhibition in 1851, and was at school through the period of the Crimean War, can no longer claim to be ranked among young men or even the middle-aged. But, with all the disadvantages of age, there is something to be said for the satisfaction and practical use of personal reminiscence. The days of school life which I can recall were practically pre-scientific, for, though one or two schools, such as the Quaker School at Ackworth, included elementary science in their programme, the utmost attempted, as a rule, was a visit from a peripatetic teacher, who came, like the dancing-master and the drawing-master, once a week or a fortnight. This was the practice at a school in Norfolk at which

I was a pupil in 1856. It was kept by a kindly old clergyman, who would, in the occasional absence of the lecturer, quack a bit himself and sometimes show experiments, not always well chosen. I remember seeing the cruel operation of putting a mouse under the receiver of the air-pump and extracting the air. And though Stockhardt's "Experimental Chemistry" was the text-book, the boys made no experiments for themselves, but were required to commit to memory passages from the book, such as "iodine has a violet vapour." There were no school laboratories in those days, even in the great public schools, neither was natural science so much as mentioned in the great majority of the schools in the country.

There can be no doubt that the Great Exhibition in 1851 set many people thinking, for in 1853 the Department of Science and Art was created with the object of assisting in the establishment of local science schools and classes. Many of the first created schools failed, and in 1859 the only classes in actual operation under the Department were at Aberdeen, Birmingham, Bristol, and Wigan.

The difficulty at that time arose chiefly from the scarcity of competent teachers willing to undertake the work, and a system was therefore inaugurated by which persons who passed the examinations held by the Department were considered qualified to teach and to earn payment on results. The system, with modifications, grew to gigantic proportions, and, whatever may have been said in later years in the way of criticism by those who object to all kinds of examinations, there can be no doubt that the existence of these classes served to spread an elementary knowledge of physical and natural science very widely through the country, and especially among the industrial classes, who would otherwise never have found their way into any place of higher instruction.

With regard to the introduction of systematic teaching of science into public schools and others of similar rank, there is the evidence of the Rev. W. Tuckwell, headmaster of Taunton School, who, in a paper contributed to the British Association at Exeter in 1869, stated that science had been taught at Taunton "for the last five years" and at the rate of not less than three hours a week. This was, however, a marked exception, for from the first report of the Duke of Devonshire's Commission it appears that in 1864 science did not exist in the programme of the largest and most famous schools. Very soon after this, however, systematic teaching, associated with practical work, began at Clifton, Rugby, and the Manchester Grammar School, and this example was soon followed elsewhere. Nevertheless, the Commissioners reported that in 1875, of 128 endowed schools examined, not one half had even attempted to introduce it, while only thirteen had a laboratory, and only ten gave so much as four hours a week. It was uphill work. Obstruction was rampant, not only among the headmasters, but also in the old universities to which the schools passed on their boys. The distribution of scholarships at that time was most unfair, and mischief was done by the procedure of the Oxford and Cambridge Schools Examination Board, which sent down examiners, sometimes ill-qualified for their office, who set unsuitable questions from the text-books with very little reference to the teaching.

At the present day all the great schools are provided with spacious laboratories and an equipment generally superior to that which was to be found in many British universities fifty years ago. Moreover, there is now a large body of highly efficient and enthusiastic teachers, not only in the schools for boys, but also in the high schools for girls, which have sprung up since that day. The science masters have formed an association which includes representatives of all the great public schools and many others—in all, upwards of three hundred members. The science mistresses have a separate association of their own, and as the problems they have before them are very nearly the same as those which interest the masters, it seems a pity that the two associations are not amalgamated. The existence of these associations and the position of influence to which the Association of Science Masters has attained show the changed position of physical and natural science as a school subject. There are, however, schools still where the headmaster stands in the way of the development of science teaching; there is the persistent, ignorant demand on the part of the public for those subjects only which are supposed to lead immediately to remunerative business; there is the almost total ignorance in Whitehall, in Parliament, and in the Ministry of the commonplaces of physical science; there are the indifferent methods still employed in classical teaching whereby an enormous waste of time is incurred: all these are circumstances which operate perennially against that kind of recognition of physical science in education which is essential to national progress, and must continue to be the subject of conflict until a state of balance between the advocates of the old and of the new has been established.

From the schools we may now turn to see what has been accomplished at the universities. In the early sixties of the nineteenth century the position of science at Oxford is indicated by the fact that Dr. C. G. B. Daubeny occupied down to 1867 the chair of chemistry simultaneously with that of botany. An undergraduate who chose to "go in for stinks" could attain a degree, but it was B.A. Daubeny's successor, Sir Benjamin Brodie, was a distinguished chemist, and in his evidence before the Royal Commission in 1873 he plainly stated his view that Oxford did nothing to extend scientific knowledge—that is to say, that research was not encouraged. At Cambridge things were in much the same position. There were some distinguished scientific professors, of whom Stokes was one of the most eminent, but there was no university laboratory, though one had been opened at St. John's College. At this time and for 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. 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