SIR WILLIAM RAMSAY.

THE 1904 meeting of the Society of Chemical Industry, held for the first time in the history of the organization in New York, is rendered memorable by the visit of its president, Sir William Ramsay, K.C.B., F.R.S. As retiring president of the society he presented the annual address, selecting as his subject "The Education of a Technical Chemist." Sir William's vast experience in university chemical instruction, an experience that extends over thirty years, lends to his suggestions a peculiar force. Those who wish to know something of the distinguished English chemist's brilliant career may refer to the SCIENTIFIC AMERICAN of July 23, 1904, from which issue the accompanying portrait, specially taken for the SCIENTIFIC AMERICAN, is republished. We print below the major portion of his address, believing that its recommendations will receive the approval of most of the university professors in this country who have charge of chemical laboratories.

THE EDUCATION OF A TECHNICAL CHEMIST.*

By SIR WILLIAM RAMSAY, K.C.B., F.R.S.

IT is customary in our society for the president to give his address when he is on the eve of retiring, and I have looked for hints in those of my predecessors. I had thought that perhaps some suggestions dealing with the training of technical chemists—a subject of which I have now had over thirty years' experience—might have been favorably received.

Much has been said about the right course of training for a technical chemist, and the example of our Continental friends has been freely cited. No doubt we have much to learn from them; yet there are some first principles which lie at the root of the whole matter, and which I will venture to lay before you, in the hope that they will commend themselves by being self-evident.

The education of a chemist (and the word "chemist," of course, includes the qualification "technical chemist") must be conceived in the sense that it consists in an effort to produce an attitude of mind, rather than to instill definite knowledge. Of course the latter must not be neglected; the definite knowledge may be likened to the bricks which the architect has at his disposal in erecting a beautiful building; he knows their shapes, their capacity for resisting stresses, and, in short, what can be done with them. But the conception of the design is the result of many attempts to create; just as the poet has to utilize words, or the architect bricks, so the chemist has to know the materials with which he is dealing. The training of a bricklayer, however, will never make a man an architect; nor will the dry research of a grammarian train a poet. In short, it is the inventive faculty which must be cultivated.

Here I am met by the criticism—"The inventive faculty must exist; it cannot be implanted." "Poeta nascitur, non fit." I deny it. There are some persons whose dislike for the investigation of Nature is ingrained. But such persons are few. It is unlikely that they will ever begin the study of natural science, unless impelled by too expectant parents. My contention is that most of the lads who enter a chemical laboratory are able to receive some inspiration, or to have a latent inspiration developed, which will fit them to become inventive chemists.

Now how can this be brought about? The answer is perfectly simple: by offering them examples. Every teacher in the laboratory, from senior professor to junior assistant, must be engaged in research, and, most important of all, they must not be reticent, but willing to converse freely on their problems. It is that which creates a "chemical atmosphere."

There are some simple ways of furthering this spirit of research. First, as regards the students. I regard it as a mistake to provide special laboratories for different classes of students. If students of organic chemistry are walled off from those who are working at analysis, then neither set knows what the other is doing. The best instruction that a student can get, he acquires in having to explain his operations to his neighbors. Now it is customary for the study of organic chemistry to follow on that of inorganic; the organic student is usually the senior; and it keeps up his knowledge of inorganic chemistry if he has frequently to place it at the disposal of his neighbors who are making routine analyses. They, on the other hand, cannot help seeing the very different processes employed by the organic man; and they insensibly learn a number of tips and dodges which prove of service to themselves at a later stage.

Of course, for complicated researches, where much elaborate apparatus is erected, special rooms are necessary, but I have noticed frequently that the inhabitants of these rooms hold informal receptions, and have pleasure in exhibiting the result of their skill in manipulation and in glass-blowing.

In some laboratories a trained glass-blower is kept on the premises. There cannot be a greater mistake. If the members of the teaching staff are glass-blowers, "es geht von selbst," as the Germans say. The whole laboratory becomes proficient. Each imitates the other. No doubt advice is often given which refers to the folly of paying sums for apparatus which it is possible to construct with little trouble, after knowing how; and the money is better spent. And glass-blowing is an all-important adjunct to research. I cannot imagine how anyone can stand the annoyance of having to wait for hours, possibly for days, for the repair of a piece of apparatus, which would probably take fewer minutes

if the owner was able to manipulate a blow-pipe. Nearly the same may be said of the mechanic's place in the laboratory. Here, however, the work is slower, and in many cases the mechanic's services may be required; but for small repairs, such as soldering, repairing, contriving stirring apparatus, electrical apparatus, etc., much may be done by the student himself without any direct teaching. I confess, however, that a mechanic is necessary, if only to see that the tools are kept in order.

After the preliminary year I do not think it advisable for the student at once to commence research. There are the usual subjects of complex qualitative and simple quantitative analysis to be mastered, separations, gas analysis, and the preparation of typical organic and inorganic compounds, besides physico-chemical operations, such as vapor densities, determinations of molecular weights, conductivities, and electrical separations. But the time spent on these may easily be too much extended. A fairly good student should have done enough, in a year and a half or two years, to place him in such a position that, if necessary, he can help himself when he is face to face with an analysis which he has not made before. By mixing research students in the same laboratory with others at all stages of advance, the man who is working at analysis insensibly gets to regard his operations as partaking of the nature of a problem, and pursues his work with the greater interest. Moreover, it is not difficult to intensify this view of the question by contriving variations on ordinary routine; the determination of calcium and magnesium in a shell; the estimation of phosphoric acid in a bone; the Dumas method for nitrogen applied to a dried mouse; the analysis of the gases of respiration of a fly kept in air confined in a tube over mercury, and so on. When an analysis is regarded as a problem, it gains greatly in interest. And it can always be checked by a duplicate, and if necessary a triplicate. It often happens, moreover, that the research work of a senior student is greatly helped by analytical work which can be safely entrusted to a junior. In this way double interest is gained—in the problem set, and in the research which the solving of the problem furthers.

Above all, not too much teaching. The essence of scientific progress is the well-worn method of trial and failure. It is simply horrible to think of the travesty of teaching in vogue in some of our colleges, where everything is provided, and where the students add one solution to another by word of command, and record their results in special notebooks constructed for the purpose. What do they learn? To obey? That should have been taught in the nursery. Manipulation? Manipulation consists in constructing what is required, not in using what is given. I had rather see a youth commit the *Æneid* to heart than carry out such time-wasting, soul-destroying routine operations. The first may result in a stronger memory; the second is fatal to all originality.

Let me consider the matter next from the point of view of the junior staff—the assistants, or whatever they may be called, "Privat-docenten," lecturers, instructors. It must never be forgotten that these young men have their way to make in the world; that it is unjust to treat them as teaching-machines; and that the only opportunity given them to make their mark is to afford them all possible encouragement to further the aims of their science, for in doing so they will further their own aims. They must become known; and without publication of their work they will remain unknown; and without reasonable leisure for research they will be unable to publish. Hence the duties of the members of the staff of a laboratory should be so arranged that at least half their time is available for research. Again, I am a firm believer in encouraging joint work done by assistants and students; the student gains much, and the assistant gains an assistant. Moreover, he learns the chief duty of a professor—the need of retaining in his mind problems for solution, and the art of getting the most out of his students in encouraging them to think for themselves. It is, indeed, an apprenticeship, where the young teacher learns his trade. He must have tools to work with; these tools are the students who act as his assistants. I regard it as essential, therefore, that the laboratory should have such a number of assistants that each one has half his time at his own disposal.

But, it may be urged, the number of assistants must necessarily be much greater than the possible vacancies in chairs, and it must therefore follow that many men will grow old in subordinate posts, and grow sick with hope deferred. Here the manufacturers should step in. A man who has had such an experience as I have sketched is invaluable, if he is not too old, as a works chemist. Here I may justify my opinion by citing the practice of many German manufacturers; it is the rule, not the exception, to induce the assistants from university laboratories to enter their works.

We come next to the senior teachers, or professors. The first point I would urge is that, while it is possible to lecture to as many students as the largest lecture room will hold, it is not possible to supervise the practical work of more than, say, forty or fifty students. The professor should always know what every man is doing. It is not necessary that those who are engaged in routine work should be visited every day; they are under the care of assistants; but it is necessary that the professor should be able to gauge the capacity of each of his laboratory students; for only thus can he tell whether they are profiting by their studies. The reason why the old laboratories of Liebig, of Wöhler, and of Bunsen are regarded with such loving memory by those who were the students of these great men

is that the total number of students was small; they formed a family party, where the individual character of each was known, and where the father lived among his children, and was able to distribute correction, reproof, and instruction in righteousness. Hence the necessity for limiting numbers. Now, if there are forty students, and the professor spends ten minutes each day with each—no great allowance of time—simple calculation shows that more than six hours are gone. I think that two hours is ample for the professor to spend daily in teaching laboratory students. Of course at some critical moment he must spend a much longer time with one; it may be several hours; but that should absolve him from attendance on that individual for the best part of a week. It is better to mix example with precept, and unless a large part of every day is given to research, the professor loses the attitude of mind which it is his duty to cultivate in his students. It does not do to let a day pass without making some effort to continue research; the habit is only too easily lost; it is like all arts; the successful pianist or violinist spends many hours each day at his instrument, and if the acrobat were to take a month's holiday, he would require to begin to learn his trade again. Moreover, it is only by continually keeping his hand in, and his mind turned on his own research, that the professor can conceive new problems, some of which are simple enough to form the best introduction to research to be carried out by his students.

Again, in a large laboratory, the time occupied in the details of organizing is so great as to make a heavy call on the energies of the professor, who is necessarily the director. There are parents to be seen; notebooks to be read; correspondence with old students in search of employment; apparatus to be ordered; servants to be directed; in short, the whole management of a business in addition to the work of teaching and research. The cares of management grow very rapidly with the increase in size of the laboratory, and many of the duties cannot be delegated. Moreover, there are the calls of public duty which often press very heavily on the successful scientific man. Add to these the share which it is always necessary to take in attending university councils, and it is manifest that the administrative duties should be simplified as much as possible.

If the reputation of the professor is such that students crowd to his laboratory, my counsel is, do not build larger laboratories, but appoint a new professor, with a separate chair, and a new laboratory; but do not make your man of talent a mere administrator.

This brings me to consider the method of appointment to chairs, and that involves the government of the university. It is a large question; but as the reputation of a university is entirely dependent on the standing of its professors and teachers, it must be considered.

There are as a rule three methods of appointing to chairs: one is selection by a council or committee—by the governing body of the university; and this, in fact, amounts to selection by the principal or president, for as a rule the principal or academic head of the university is regarded by the council of outsiders as the best judge of scholastic matters. The second method is selection by a committee of specialists appointed by the university; if, for example, a physical chair is vacant, it is filled by a committee consisting of four or five eminent physicists, themselves not connected with the university in which the vacancy occurs. The third method, and it is the one which commends itself to me, is selection by a committee of the faculty in which the vacancy occurs, after a reasoned report in which the relative merits of all the possible candidates are discussed.

The reason for my preference is a very simple one: it is because selection by persons belonging to the same faculty of the university unites two qualifications in the persons of the electors—competent knowledge on the one hand, and self-interest on the other. Choosing, as an instance, a vacant chair of physics, the committee of selection would consist of any other professors of physics in the university, provided there were more than one; the professors of chemistry, biology, mathematics, botany—of all sciences to which physics is a fitting introduction. These men of science either know, or can make written inquiries about possible candidates.

It is true that the academic head of the university—the principal or president—may be influenced by like motives, and that any selection which he may make may be made on very similar lines, after a similar inquiry. But the filling of a chair is not a single-handed job; if it is single-handed, it is likely to become a job; either the principal is not able to get the required information, or his judgment is not so sure as that of those colleagues more intimately connected with the subject of the vacant chair. Selection by the principal may succeed; selection by colleagues of the same faculty practically always succeeds.

As for selection by a committee of outsiders, they have no feeling of responsibility. From personal experience, I know that their aim is satisfied when they have elected a man who will not disgrace their choice; they do not necessarily select the best man. I know, having had to act as an elector by all three methods, that one is much more particular when one has to choose a fellow-teacher with whom one has to pass one's days. From what group of persons should a professor be chosen?

There are large universities, and there are small ones; and obviously the professors in the smaller institutions will be available for selection to the larger ones, with their greater field of usefulness and their higher emoluments. Should the professors in the

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smaller universities have justified their election, they will doubtless be the first to be considered in filling the more important chairs. And for the chairs in the smaller institutions, the assistants will be available. They will have published work of a nature to make their names known as promising investigators, and they will have commended themselves to their chiefs as capable men to whom the management of a department may well be intrusted.

The choice of the assistant from among the senior students may be left entirely to the professor with whom he has worked, and who is best able to judge of his powers. He will doubtless have filled the position of a student-demonstrator, in looking after junior classes; and his frequent appearances at the local scientific society will render it possible to estimate his ability as a lecturer.

And now let me discuss a question which has not given difficulty in America, I understand, but which has greatly retarded the advance of knowledge and research in England. I refer to examinations. It may well be introduced here, for it may be asked, Should only a graduate be recognized as worthy to occupy a junior teaching position? To this I would reply, Let the choice be free. I have often seen men whose circumstances, or whose character, or whose deliberate choice has led them to abstain from taking a degree, and who, nevertheless, are most successful investigators, well able to increase the knowledge of their subject, and who have proved most inspiring teachers; and, on the other hand, I have perhaps more frequently come in contact with graduates whose only claim to recognition was a parrot-like ability to repeat what had been told them, and a knack in gaging the idiosyncrasies of an examiner. The older I get, the less I believe in university degrees as a test of capacity. Perhaps the reason is the manner in which degrees are awarded in England; the degree follows on one, or at most two examinations, often by men who know the candidate only as a number, and whose idea of examination often is to set questions to trip the candidate, and not to draw out what he can do. Indeed, it raises the question which I have mentioned earlier in this address: the examination is so contrived as to elicit what a man knows, rather than what he can do.

Now here, again, there are certain obvious truths which have often been stated, but too often ignored. The student, working under the eye of the professor and of his assistants, undergoes a daily examination. He may not earn marks; but, none the less, he impresses his teachers with some conception of his character; and the impression is made rather by what he can do, than by what he knows. The qualities tested by such examinations as have been customary for the past forty years in England are the last which one would wish to have in a student of science—readiness of memory to the exclusion of deliberate judgment; the faculty of spreading knowledge thin, and making a veneer of scientific facts instead of the power to correlate them and increase their value; and the skill to gage the capacity of and hoodwink the examiner, instead of the power to incite enthusiasm in others. A sound judgment, though it may be a slow one; persistence in struggling against obstacles; the knowledge where to get information when required, and to use it when found; and the inventive faculty—these are the qualities required, and they can be gaged only after long-continued observation. Moreover, the pernicious system of competitive scholarships and fellowships, instead of eleemosynary support given to the necessitous and deserving youth, has also contributed much to the debasement of the scientific spirit; for it has early implanted in the young mind the idea that to outrun his fellows, and to work solely for a money reward, are the ends to be aimed at, instead of the joy of the exercise of a divine gift, and the using that gift for the benefit of man. It is true that to earn money is a necessity; it is in no way a wrong aim; but it is not the chief aim; and money should be earned as a reward for useful labor, not for success in scholastic competitions. Under present circumstances, as scholarships exist, and must be awarded by examination, it requires considerable ingenuity to devise a method of examination which shall pick out men who will make a good use of them. I recently gave as a question for my own students, "Describe shortly the researches which have been going on in this laboratory during the past six months;" and I found the result very satisfactory. The question put a premium on the interest which a student should take in his friend's work, on the intelligence in following it, on his powers of description, and on his suggestiveness where invention had to stand for want of accurate knowledge. The after-effect of such a question, too, will be considerable. The students will endeavor in future to follow the researches of their neighbors with more understanding than they have done.

A question sometimes debated is whether the professor should lecture to junior or to senior students. Should he introduce the young student to the study of chemistry, or should he lecture to the most advanced students on recent developments of the subject? My reply would be, that students are much over-lectured. The object of lectures is more to open out a subject, and to direct a student what to read, than to give definite information. And for that reason I think the senior teacher is the best for junior students. Experience has generally taught the older man how to make his subject interesting to beginners; he has learned the art of repetition without showing that he repeats; he does not travel too fast on roads untraveled before by the young student; and he is more lenient to their often absurd efforts to form correct conceptions. On

the other hand, the senior student is less exacting than the junior; to him the matter is more important than the manner of delivery; if the lectures prove useful to him he is ready to excuse any want of judgment on the part of the young teacher. But we have found it advisable to ask individual advanced students to deliver short courses of lectures on special subjects of which they have made a study; no fee is charged for admission to these lectures; and they are much appreciated both by the deliverers of the lectures, as a field for practice, and by the students, as an easy way of becoming acquainted with special branches.

It consequently appears to me futile to extend courses of lectures to more purely technical subjects. The ideal plan of education for technical chemists would be some system analogous to the apprenticeship of engineers, after they have been educated in the science; that is, after the correct habit of mind has been largely formed. But it is difficult to see how this can be brought about. The obstacles in the way appear to me to be insurmountable. The chemical manufacturer is not willing to throw open his work to students, nor would he do so even if very considerable premiums were paid. Indeed, in England, it is not uncommon for the "chemist," so called, to be refused admission to the works, and to be confined to the laboratory. In the larger German works, where many chemists are employed, it is possible for a young man to gain the requisite experience.

I have wondered if it might not be possible to establish a training school for technical chemists somewhat on the following lines: To start an association having for its object the encouragement of invention, each member of which would subscribe a certain sum for the erection of buildings and plant. There would need to be a number of isolated buildings, and a considerable collection of stock plant of a small scale—still, tanks, evaporating pans, filter presses, vacuum filters, centrifugal machines, crystallizing vats, and so on. The work should be furnished with steam and electric current. Such a syndicate might let it be known that they were willing to make arrangements with inventors, or with syndicates which had secured the patents of an invention, or secured an option on such patents. The superintendent or professor should be provided with a staff of assistants, who would be each in charge of one building—that is, of one operation. Students would be admitted for an appropriate premium, as in engineering works. Supposing an idea to be brought to the notice of the directors, they would consult as to whether it should be accepted or not. If accepted, then the share of profits would be arranged with the patentee, should it prove successful. It would be committed to the charge of one of the staff, who would first work it out in the laboratory with the aid of a staff of students. If it then seemed feasible, it would be tried on a comparatively small scale, dealing with hundredweights, in one of the special buildings, those students who had investigated the process in the laboratory sharing in the larger-scale operations. The surmounting of difficulties in the transition, the perfecting of the process, the making working drawings of the requisite plant, would afford the best of all training to students; and in case the process proved a commercial success, these students who had helped to elaborate the process would be naturally the first to obtain employment in works, should they be erected. At the same time, manufacturers would naturally be anxious to obtain the services of men trained in so good a school, so that many students would be drafted off to works. Indeed, the scheme may be paralleled from the medical side; after receiving a medical education, for example, in preliminary scientific subjects, such as chemistry, physics, and biology, the medical student devotes himself to professional studies for three years. Then his technical education begins when he becomes house physician or house surgeon. After such experience, he is available for junior positions, for becoming "locum tenens," and so on.

The students in such an experimental works would, of course, have to do laborers' work; employes always respect a man who can "take his coat off." In this way he gets to know their difficulties, and to judge them fairly; to know what they can do, and what reasonably to expect.

I am by no means sanguine that such a scheme of technical education can be started. I acknowledge that it is an imperfect imitation of the magnificent schools of technical chemistry which form part of every large German chemical works. But such schools are unlikely to find a footing, so far as I can judge, in England. I cannot judge of America. Our system is, when trade is good, to let well alone; the manufacturer thinks, "I have done very well without a chemist so far; why have one now?" or, "The class of man who has served us as analyst has sufficed for our needs; he costs only £2 a week; why burden ourselves with a more expensive, even if a more skilled man?" And when trade declines, he naturally shrinks from spending money. It is the policy of "penny-wise and pound-foolish."

A stone viaduct is being built at Plauen, Saxony, over the river Syra, which contains the longest masonry arch in the world, its length being 295 feet 3 inches, measured horizontally from base to base. The new bridge will be opened to traffic about November 1, 1904. The Luxembourg bridge across the valley of Petruffe, which was completed a few months ago, has a span of 277 feet. The next longest masonry arch is in the United States, near Washington, D. C., and is known as the Cabin John Bridge. Its length of span is 220 feet.

THE LONGEVITY OF BIRDS.

BIRDS, if we consider their comparative weight rather than bulk, live much longer than mammals; but even in birds there is considerable variation. Leaving the why and wherefore, let us see what is known. We can only form our conclusions in most cases from birds living under artificial conditions in captivity. We are therefore at once faced with the question: Do we prolong the life of our captives by providing them with a regular and suitable supply of food, or do we shorten their existence by the inevitable restraint? We may do either if we consider that the average life of a bird in a free state is regulated by the rate of mortality. Few birds, or indeed any animals, die a natural death; few linger to perish by the miseries of old age and decay. Nature provides the "happy dispatch" either in the form of accident or at the hands of enemies, predatory or parasitical. We have no means of telling how long a wild bird's constitution might survive if it could manage to live to die of old age. Too frequently, however, our solicitude for our pets leads to their undoing, and post-mortems do not always reveal where we have erred; now and then we discover that a surfeit of boiled potato or some similar food has hastened the end. If we keep birds, we are constantly struck by the frailty of avian life.

It is an old German popular saying that a wren lives three years, a dog three times as long as a wren, and multiplying each age by 3, goes through a series—horse, man, donkey, wild goose, crow, deer, and oak. This, as Weismann points out, makes the life of man 81 years, and of a deer over 6,000, and although crows can manage better than we can they hardly live 2,000 summers. Small singing birds seldom live over 20; their ages in captivity vary from 8 to 18. Naumann states that a canary will live 12 or 15 years, a nightingale 8 or 9, and a blackbird about 12. Compared with our threescore years and ten, which we lords of creation have the audacity to consider as the standard, these ages are not long. A magpie has been known to reach 20, but others of the crow family have done better; ravens have lived for 100 years or more—one authority states 200—and in a wild state it is possible they may last longer.

"Parrots, which look as if they had lived for ages, they are so wise" (the borrowed expression is very apposite), have several times been known to pass their century. No record, unfortunately, has been kept of the result of the experiment made by an old lady of eighty who purchased a parrot to see if it really would live until it was a hundred. Humboldt, in good faith, tells of a parrot, living in Maypures when he was on the Orinoco, which conversed in an unknown tongue; the Indians said they could not understand it, for it was the language of the long-extinct Aures. Parrots as a rule are quick at picking up recent language, especially if it is vehement; we must take the statement of the Indians for what it is worth. Longevity is not uncommon among raptorial birds; a golden eagle lived in captivity in Vienna for 104 years, and we do not know what age it was when captured. A vulture in the same place lived 118 years, and a falcon is said to have reached the ripe age of 162.

Eider ducks are supposed to live for 100 years, and wild geese may exceed that period, which, however, is considerably below the time reached according to the German saw; swans, which certainly live a long time under favorable conditions, are stated to live sometimes 300 years.

Naturally, the statements about longevity in birds and mammals are liable to exaggeration; Sir Thomas Browne, in his "Vulgar Errors," threw doubt upon the longevity of deer; in such cases, however, as well-known captive elephants, crocodiles, and giant tortoises the evidence is good, and whales have been captured with ancient-dated harpoons embedded in their blubber. The great question of the duration of the life of an animal turns upon one point—How long is it necessary for a creature to live in order to insure the perpetuation of its kind? It must produce a sufficient number of offspring to leave an average of two descendants, in order that the race may not die out. What, then, does this mean? Simply that the chances are against so many young creatures—enemies lurk on every side, accidents, starvation, storms, threaten them so constantly that a vast majority go to the wall before they reach maturity. To maintain the balance of numbers each pair must leave a couple of offspring, and no more; the rest must fall out of the race, and so they do. If, therefore, a bird lays but few eggs, and the young are exposed to many dangers, it must live long enough to produce a minimum balance over and above the number which are wiped out. Weismann's calculation about the golden eagle, whose life may last, say, 60 years, will serve as an example. Suppose that maturity is not reached for ten years—most birds are mature long before this—and two eggs are the average number laid, we shall have 100 eggs in 50 years, and of these only two will develop into adult birds. This is a terrible fact to realize when we consider that a similar waste of life occurs throughout the animal kingdom; but it requires no stretch of imagination to see what would be the inevitable result if a slight—ever so slight—increase in numbers occurred generation after generation. Without entering into the arguments, it may be roughly stated that birds have more odds against them than mammals, and consequently require a longer life to achieve the object of this life; in other creatures, especially in invertebrates, an increased fertility provides for the struggle against the drain; they live a shorter time, but produce more young—Manchester Guardian.