prove the wisdom of these plans. And whether this confidence be misplaced or not, they think they have a right to expect that no unfriendly attitude will be taken towards the college while the important experiments only recently begun are being pressed steadily to a decisive conclusion.

Very sincerely yours,

E. M. GALLAUDET.

THE TEACHING OF SCIENCE.[1]

THE subject chosen for this paper, The Teaching of Science, is a broad one; far too broad for more than a very superficial treatment in the time allowed, but it is my purpose rather to call attention to certain general ideas in which too much of our modern science teaching seems to be at fault, and to try to suggest lines in which we may hope for improvement, While I use the term "Science," I have particular reference to the so-called natural sciences, though perhaps the ideas are capable of a wider application.

Among these natural sciences there are certain ones to which my attention has been more closely drawn, but I believe the principles which should be at the basis of instruction in them will apply equally well to all.

Why do we study the sciences? how far do we attain our ends in this study? and is it possible for us to attain them more completely than by our present methods? These are the three questions I desire to consider.

1. Why do we study the sciences? Were we to judge from the great mass of science teaching of the present day, we would be obliged to answer unhesitatingly that the natural sciences are taught chiefly at least, for the purpose of acquiring certain facts which are supposed to be of the necessary stock in trade of a well educated man or woman, or perhaps I should speak more correctly, were I to say, facts which every well educated person ought once to have known sufficiently well to have passed an examination in them; in as much as, for better, for worse, most have forgotten a great share of these acquired facts. I say were we to judge by the way science is taught, though few teachers would admit this mere acquisition of facts to be their aim in teaching. If we should inquire of these teachers, they would undoubtedly tell us of the "disciplinary value," that vague expression often heard and so unsatisfactory to the pupil, as he repeats his *amo, amas, amat*, or pauses to rest on his *pons asinorum*.

In all education we have two aims; the direct furnishing of the mind with a store of facts and the development of the mind so that it can utilize these facts and attain others; we teach, and we teach how to learn, Now there are undoubtedly, a vast multitude of facts in the natural sciences, which are of practical value in every-day life; but after all these are of little importance compared with the tremendous development of the mind which may be and ought to be gained by this class of studies.

The natural sciences are pre-eminently the studies to develope the reasoning powers; every step has been and can be logically worked out from the preceding; nowhere else do we find that gathering of facts, perhaps very few in number, under an hypothesis, and then, by gaining new facts by study and experimentation, the development of the hypothesis into a theory and, it may be, a law. The best instruction in logic I ever had was in a class of a dozen or so, where we had each made quite a series of apparently unconnected experiments in physics, then were given the task of arranging our descriptions of these experiments in their proper sequence, discussing in the class room our arrangements and defending each his own choice.

The chief aim in the study of science should be this development of the reasoning power; the teaching of independent thought; and the acquisition of facts in themselves, however important some of them may be, should invariably be made subordinate to this. I ought in this connection to refer to what is often spoken of as a very important aim of science teaching, that of training the power of observation. Of course when rightly studied, science does train this power, and even the most superficial elementary course in any science cannot fail to make the scholar now and then a little more interested in observing what goes on around him than he otherwise would be; nevertheless the training of this power is of value only just as far as it is a means of training the reasoning power. A man may have a marvellous gift of seeing everything and seeing it accurately; but this gift is of value to him only as far as he can utilize it as a basis of thought; and therefore I would hold that the training of the power of observation is embraced under the all important aim of science teaching, the development of the mind, the development of the power of thought.

This should be the chief aim of all instruction in natural science; all else is of little use.

2. Now how far does the instruction given in our institutions of learning, our schools, academies, colleges, and universities, tend to carry out this idea?

Until until quite a recent time there has been little or no instruction in natural science given in our lower schools; in our cities at the present time there is more or less of an attempt being made to introduce the study of chemistry and physics. I leave out of account for the present the kindergarten, where there seems to have sprung up a germ of the true idea of science teaching. The most that is expected in our common schools is that the teacher shall hold a few recitations from a text-book, from which the scholar is supposed to familiarize himself with a large or small number of facts and possibly to learn the statement of a few laws or theories. In the higher schools, the academies, and some of the colleges, a somewhat greater task is attempted; here the text-book is supposed to cover practically the whole science and a correspondingly great number of facts is sought to be memorized; with a couple of recitations a week, the student is expected to go through "fourteen weeks in chemistry," or physics, or geology, and to have learned the gist of the whole science. Here we have a mere feat of memory. of just as much value, perhaps, as the committing to memory of so many lines of "Paradise Lost," certainly no more. In many, perhaps most, cases the teacher is as ignorant of the subject as the scholar, and must have the text-book continually open in order to recognize if the answers are correct. One college in Kentucky advertises to give complete, thorough, and practical courses in each of the sciences in a term of ten weeks; think of acquiring chemistry, physics, geology and astronomy in less than a year, and not neglecting other studies in the meantime! Of late, however, it is coming to be very generally recognized that scientific instruction cannot be imparted without experiment, and so the teacher performs before the class some of the simpler experiments. This is indeed a step in the right direction, but in most cases only a very short step. An experiment merely as something for a class to look at or be entertained by is valueless; indeed the only value of an experiment is in making clearer the principle it is intended to illustrate. If it fails to do this, it fails to accomplish any thing. I remember asking a young lady, who had a few months previously passed a fine examination in chemistry in one of our higher institutions, if she remembered how oxygen was made, "Oh yes," she said, "why! the professor took something black and something white, and that was oxygen." Some features at least of the experiment had made an impression. In most of the colleges and academies for ladies, I think it is no exaggeration to say that science study as usually conducted is of no value; the only science which there is an attempt to study at all thoroughly is botany; and even here it is questionable to my mind if the student get from this any thing which justifies the time put upon it, except that incidentally the fresh air exercise obtained in gathering specimens provides that which is much needed by all young ladies. The end usually sought is ability to analyse, by the aid of tables, the common plants, rather than the study of these plants. In no other science is the absurdity of this method of study so apparent. In the chemical laboratory it is true that the use of analytical tables is a prominent feature, but there seems to be at least a practical end attained. Imagine a study of zoology or of mineralogy which should find its end, not in studying the animal or the mineral, but in merely finding out by a set of artificial tables what it is, and we see the fallacy in calling it science. I believe it would be better for all students of botany, and I think

[1] Read before the Kentucky College Association at its latest meeting.

I may add, of chemistry as well, were all analytical tables destroyed.

This brings us to the subject of laboratory work, the *sine qua non* of scientific study. This is at the present day, so far acknowledged that in none of our colleges, and few of our better high schools and academies, would the instructors think for an instant of trying to teach certain sciences without the laboratory. We may thank the chemist for the introduction of the laboratory idea. But to-day there are few colleges, except the larger, and still fewer of our academies, where we find physical or biological laboratories; yet, even with the laboratory, we have by no means reached the ideal in scientific instruction, save in a few institutions. Take, for example, much of the laboratory instruction in chemistry. With a book of directions before him, the student performs certain experiments; with a set of tables, he goes through the process of perhaps separating the metals, and may become even a good analyst, without having profitted to any considerable extent by his work, all being performed mechanically, In the physical and biological laboratories there is far less danger of this misapplication of scientific study, and this largely from the fact that laboratory work in these sciences is a more recent idea and less systematized. In our modern education there is a most pernicious tendency, well exemplified in botany and chemistry, as we have seen, but found in other studies than the sciences, toward machine instruction. Everything is most systematically arranged, and students, bright and dull, are all dosed with so much per diem. The text-book is made everything, and the teacher nothing; and, as a result, we are losing our teachers. Their function seems to be no longer to teach, but merely to see that the required dose is taken. The scholar loses his individuality, and merely becomes like the Strassburg goose, cooped up and so much food forced down its throat so many times a day, the only demand being that on examination day its liver shall have attained the regulation size. In our larger colleges, where each instructor is confined to but one branch, and is, as a rule, an expert in teaching that branch, things are more as they should be; the true aim of science stndy is more nearly attained. But here these instructors are met with the difficulty that the student has so long been the victim of bad methods that it is almost impossible to successfully iutroduce the good ones. Then we must further even bear in mind that the great mass of the youth of our land do not have the advantage of college. It is but a small percentage who even enter the high school. Has science nothing to do for those whose school-years are few in number and who are to make the great bulk of our citizens? I believe she has, and will try to point out, or at least to hint at, what seem to me to be the methods by which science-teaching can be made to accomplish its true mission.

3. That which we must seek to do may be expressed very simply. We must seek to so teach science that the student, be he man or woman, boy or girl, or even a little child, shall be led to think about phenomena. If the great good to be attained by science study is the development of the power of thought, we must do all in our power to induce thought. The kindergarten, child's play, as too many consider it, may teach us an important lesson. It is play indeed, but the child is led to think about his play, and the effect of kindergarten instruction may be clearly seen in those who have had the advantage of its training. It is surprising how few even of our college students are capable of independent thought. We see the lack of this thought in the sets of answers to examination questions now and then published, generally with the idea there is something humorous about them. They may for the moment excite our laughter, but rather are they a cause for pain, as bitter examples of the deficiency of our system of education. I would have science-teaching begin with the first of a child's education, or rather it should begin at home, long before the child is thought old enough to study the alphabet. If the child is taught to notice anything in nature, be it a stone or an insect or a little rill of water, he will need but little encouragement to ask questions about it, and, by a judicious directing, he can be led to do his own answering. I have seen a little girl, hardly six years old and unable to read, reason out for herself the general principles at the basis of evolution by merely calling her attention to a few little clumps of blue and white and yellow violets, growing in close proximity. In the lowest grades of our schools the teacher should encourage children to collect all kinds of natural objects, and those found in any locality will be amply sufficient for science study. One of the "plays" in the kindergarten is for the children to plant different kinds of seeds and watch their growth. Similarities and dissimilarities attract attention. We all know the innate desire in every child to dig up the recently-planted seed and see how it grows. The kindergartner wisely utilizes this.

In the few years of common school, the child will have perhaps not the least systematic scientific knowledge, but he will have learned to think about all that goes on around him, and then when, at a later period, he takes up the sciences systematically, he will find that he is already possessed of a great number of facts which will almost arrange themselves, and that not merely in an orderly manner but, what is far more important, intelligently. In our common schools I would have science instruction given from the lowest to the highest grade, and this wholly without the aid of text-books. A short time should be taken every day, with each class, for this purpose, the teacher endeavoring to interest the class and draw them out on some natural object or phenomenon.

It matters little what the particular science chosen may be; if there be one in which the teacher is especially interested, that is the one to use; a handful of marbles, a base ball, or a bat, will serve to interest the boys and instruct them on many a point in mechanics; a few rubber bands stretched across a cigar-box, in sound; a mirror, a burning-glass, and a prism, in light; zoology affords, throughout its whole field, countless specimens for entertaining instruction to the young; they may in familiar examples, and in specimens of their own collection, study the different developments and uses of homologous organs, as the arm of man, leg of mammal, wing of bird, and fin of fish; or the different modifications of the same organ, as the comparison of the eyes of vertebrates with those of insects and molluscs; or the different organs used for the same purpose, as the organs of prehension in man, monkey, elephant, parrot, snake, lobster, and insect; or, on the other hand, they may find it more interesting to study from a systematic standpoint, finding out for themselves the differences between animals of different classes, as between herbivores and carnivores, insect-eaters and rodents, insects and spiders, one-shelled and two-shelled molluscs. It may in some localities be possible to compare some of these modern forms, as snails, with very similar fossil specimens near at hand; and here we can call geology and paleontology to our aid in work with children. And again, just to allude to one more science available for this work, the kitchen closet, with the occasional aid of a few cents' worth of some acid or the like at the drug store, will afford us most ample opportunity of impressing the most important lessons of chemistry; combustion, respiration and decay, pure air and ventilation, dryness as a disinfectant, fusion, solution and crystallization, and a thousand similars, many of them of great practical value in their applications, but far more useful as agencies for thought development, come to our mind as possibilities in chemistry as a science for the young. I might take up each science in its turn, for each can easily be made to serve its purpose, but these examples will illustrate what can be done in any one of them; not one thing mentioned but is within the reach of any faithful common school teacher; but how long will it be before we see any general materialization of such ideas?

Thus far I have referred to scientific instruction in the lower schools, which do not so directly concern the members of this association; the same principle, however, is applicable to the higher schools, and we must not forget that the lower schools, which lie at the basis of our civilization, are just what our higher institutions make their teachers. When the high school and academy are reached the possibilities in scientific instruction broaden vastly. In the case of those who have had such elementary training as described, the task is easy; but the problem is harder with others, owing to the difficulty in teaching correct methods of study to those who have for a period of years been drilled in bad ones. Eight or ten years of learning by rote are enough to unfit a child for anything else. Two points we must have before us if the scientific work is to be done for the purpose of attaining its chief end: we must as far as possible lose sight of study for either practical ends, or for the purpose of general information; and we must as far as possible adopt laboratory instruction. In regard to the first point, we suffer more in our academies and high schools, but perhaps also in our smaller colleges to a lesser extent, from rushing through these abbreviated courses in the sciences, than anywhere else; here it is chiefly that we find the task set of giving every student an outline view of every science, embracing as many diverse facts as his memory can hold. Particularly are the fairer sex compelled to suffer in this regard. Better far to take a single science and develop it much in the same way, though more systematically and to a more extended degree, as that already suggested for use in lower schools.

As regards the laboratory work, it may be very simple and inexpensive, but it is an invaluable aid in science teaching; a table, a dissecting case, a lens, a few glass jars, a few chemicals, and if possible a small microscope, slides and cover glasses, will form a sufficient equipment for a very practical biological laboratory; even some of these are not absolutely necessary, as the dissecting case may be replaced by a good knife. For botany the lens, or better the microscope, is almost alone needed; for mechanics, a few of the most familiar carpenters' tools and a bench for work, comprise the necessaries, while in the other branches of physics but little is needed. Even in electricity, a few pieces of copper and zinc, some old electric light carbons, a few chemicals, some wire and a magnet, will go a long way in instruction. Chemistry is supposed to require the largest outfit, and yet I think that some of our dealers in such goods could make no little profit by fitting up collections of chemicals and apparatus for the purposes we are considering, at the cost of not over a dollar for a full set for each student, and five times that amount for the teacher's set; in other words, expensive equipment is wholly unnecessary for elementary laboratory instruction in any of the sciences, indeed in too many cases, an extensive set of apparatus and fittings distracts the attention of the student from the experiment he is studying. Now in using the laboratory, let it be clearly understood that there is no "practical" aim sought, but merely that the student shall think out for himself all the facts connected with the experiment; if it be considered that a knowledge of certain facts is necessary to his education, let him be shown where in the dictionary or encyclopedia these facts may be found.

Our brains are limited in their capacity, and if we load them with that which is of little or no use, there will be little space left for that which is of more importance. Let the student know just where to go for these facts, rather than have his mind filled with them in preparation for examination day. Our aims in science study will be best attained by a few simple experiments, carefully studied and reasoned upon, and these every higher institution ought to furnish.

When we come to science instruction in college, the same train of reasoning applies, but here it is far easier to carry out our principles. It obtains in college, as in the lower institutions, that the student is expected to gain at least a smattering of the chief sciences; still, with our optional studies, the chance for obtaining the true aim of science study is far greater. One reason for this is the increased time allowed to each subject, and the fact that the teacher is more or less of a specialist in the branch or branches he teaches. Let us in this connection look a little more closely at the science with which I, as a teacher, am more familiar than any other, that of chemistry; for this will serve us as a type of them all. Chemistry is studied at college by two classes, one that desires to gain a thorough knowledge of the subject, usually for some practical end, and the other, generally comprising all the students who pass through college, desiring merely to gain a general view of the whole field. Since a thorough study of the chemistry of the non-metals is necessary as a foundation for further prosecution of the science, and since the time required to lay such a foundation is fully as much as the majority of the students can spend on the whole subject, it has been in many places in time past, and indeed perhaps we may say is to-day, the general plan to let the two divisions work in entirely different plans, the one class going superficially over the whole subject of chemistry in a term, while the other proceeds slowly and thoroughly. This is, I believe, a great mistake; the rapidly moving class is at just the same disadvantage as the academy and high school classes we have already noticed; they are trying to learn facts and statements, and thereby lose the true aim of science study. It would be far better for them by slow study to thoroughly master the principles of the science, and gain its value in stimulating thought, and in a few days' reading at a later period they could gain a far better knowledge of the whole subject than otherwise in the whole term. The student should, in the laboratory, perform after the professor each of the simpler experiments, and be questioned particularly and chiefly as to the meaning and signification of the experiment. In the quantitative laboratory he should study the metals comparatively, paying particular attention to similar reactions by which metals may be classed together, and to dissimilar reactions by which the metals may be distinguished and separated. In this way he may cut himself loose from all artificial tables except as far as he shall form these tables for himself as a result of his work (I may here perhaps be allowed, by way of parenthesis, to add that I believe it will be found more advantageous for the student, when beginning work on the metals, to examine first the effect of each of the common reagents upon all the metals, than the commonly adopted method of testing each metal with all the different reagents; in this latter case the student for the time being loses sight of comparative reactions).

The more thorough a student is in his work, the more he applies to it all his power of thought; the better his mind will be fitted to carry the science into practical work, should such be his ulterior aim. The more he works by rule, the less fitted will he be for more advanced work, and the less able to leave the beaten track.

The general principles here laid down in the study of chemistry, will be applicable to the other sciences. It will be better far for the student to cover less ground and to lay a thorough and thoughtful foundation; the further general knowledge of the subject will be easily and quickly gained whenever it may be desired. So too as regards the idea that a student should study at least a little of every science. To my mind it is better far to devote one's self thoroughly to one science or perhaps two in college; so similar are the methods of thought in them all, that he who has mastered one, can take up by himself any of the others sufficiently well to gain as much knowledge of it as a *liberal education* demands, while he who devotes himself in college equally to all will not only know little of any one, but he will almost, if not completely, have failed to gain the development of mind which science study should give him, and the superficial knowledge and facts gained will, for the most part, pass from his mind, as soon as examination day is over. With the scientific method of thought once gained, however, the facts in all other sciences, will naturally fall into such logical sequence that they will, for the most part, readily remain in the memory.

In summing up this paper let me repeat in conclusion that in my opinion, science study, to have its true value, must have ever before it from Common School to College, as its chief aim, the development of the power of thought; without this aim, it is time largely thrown away; with it, it is one of the most potent agencies in modern civilization. JAS. LEWIS HOWE.

Polytechnical Society, Louisville, Ky.

LETTERS TO THE EDITOR.

*** *Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

On request in advance, one hundred copies of the number containing his communication will be furnished free to any correspondent.

The editor will be glad to publish any queries consonant with the character of the journal.

The Question of the Celts.

I REPLY with much pleasure to Professor Haynes's inquiries in *Science*, April 8, p. 207.

The theory of the European origin of the white race was advanced by Omalius D'Halloy (who is almost as well known for his labors in ethnology as in geology) in various papers published