scope built on this plan now in use in this laboratory. Its 'Echelon' consists of twenty plates each 18 mm. thick. Each plate projects 1 mm. beyond the next succeeding plate. It has a resolving power of about 300,000. A larger Echelon with thicker plates is being built here now which will have a still larger resolving power.

It is hard to say when the practical limit of resolving power by this instrument will be reached. But it is quite certain that 500,000 is soon to be attained. When we consider that the best gratings have a resolving power of only 100,000 we see how great an advance has already been made. Zeeman discovered that in the magnetic field the spectral lines were separated into three components, but with the Echelon spectroscope now in use here it is possible to see the doubling and tripling of these components which was discovered by Professor Michelson* by means of visibility curves.

The disadvantage of the instrument is that it will not give a continuous spectrum, but its advantages in cheapness and enormous dispersion for small portions of the spectrum make it an invaluable addition to the means at hand for analyzing vibrations of light.

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THE RELATION OF SCIENCE EDUCATION IN THE SECONDARY SCHOOLS TO THAT IN THE COLLEGE AND THE UNIVERSITY.†

IN discussing the nature and the scope of the science work in the secondary schools one principle, I think, is recognized by all as being fundamental, and this is that the training of specialists is not the function of the high school. Neither is it a part of the college in any but a limited sense, while, on the other hand, it most emphatically does come within the sphere of the university.

In laying down this principle, I am well aware that by far the greater number of high school pupils never intend to continue their education in any other institution of learning, and that their future advance must be made without the aid of professional teachers. To my mind, this makes no difference. There are certain broad foundations which, if the course is to be of lasting benefit, must be laid alike for all.

The development of the pupil's reasoning power and his faculties of observation are the important objects to be attained, and not to fill his mind with masses of facts and figures, which are as surely forgotten as they are learned. Such accumulations are defended only on the ground that they are of so-called 'practical benefit;' in reality, they constitute the most unpractical portion of any school course. Such things belong to the training of specialists, and consequently to the university, and even though the specialist can obtain a great number of necessary data from books and tables, after he has completed his studies he never can acquire the necessary fundamental training in the use of reason and logic, if he has neglected these essentials in the beginning. That which I have said applies to all branches of study—to the languages, to history or to mathematics as well as to the natural sciences; for all of them the same broad pedagogical principles are necessary.

I have used the term 'specialist' in its broadest sense in referring to high school students. It is in my opinion as grave a mistake to develop the pupil's training mainly along the scientific line as it is to confine him to humanistic studies alone. It is just as essential that the student in biology, physics or chemistry should be

* *Philosophical Magazine*, April, 1898.

† Address of the President of the Natural Science Department of the National Educational Association, July, 1898.

well grounded in the languages, history and mathematics as it is for the other class to have a knowledge of the methods of scientific thought. In other words, I would have every high school pupil take work of both kinds, and I greatly deprecate the tendency to divide the secondary school curriculum into 'classical,' 'scientific' and 'English' from so-called 'practical' motives, for, as I have already said, these motives seem to me in reality the most unpractical. Some differentiation, no doubt, may be allowed, but none should be tolerated that will in any way be detrimental to a well balanced growth of the pupil's mind. The high schools will do good only in so far as they develop reasoning, thinking and normal citizens.

Coming to that topic which more nearly concerns us, the teaching of the sciences, it goes without saying that a smattering of a number of sciences is of no value whatever. No high school pupil can hope to become a scientist in the limited time during which he studies, nor even if time allowed is his mind sufficiently matured to enable him to have the proper point of view. As a consequence, it is of very little importance, with certain reservations, what sciences he studies, so long as he learns something of the methods of reasoning and the habits of thought which apply alike to all. Of course, it must always be borne in mind that certain sciences are fundamental to others, a considerable mathematical knowledge being necessary for physics, and undoubtedly a certain familiarity with physics is requisite before beginning the study of chemistry. Such subjects cannot be placed out of their regular order without doing violence to all; they must be kept so if the object aimed at, familiarity with the methods of scientific reasoning, is to be attained.

No one can hope to become conversant with all of the fundamental principles in any one science in any one year, or even in many years, and that this is so is evident when we pause to consider the number of lives which during the last two or three centuries have been devoted exclusively to the task of bringing our methods in the sciences up to their present standpoint. Take the atomic theory alone. How many years of toil, how many hard-fought battles, how many great names, have during the past century been devoted to its perfection! Dalton, Berzelius, Guy-Lussac, Wöhler, Dumas, Stas, Avogadro, Cannizzaro, Clausius, Clerk-Maxwell, Thomson, Mendeléef and hosts of others have given their best years to it—and what it has taken such minds to develop we expect the high school student to grasp in a day! The same with all of the great theories of modern science; all represent the present convergence of many and often diverse views, held by numerous men who honestly fought and toiled in their chosen fields and whose names will live for all time. Shall subjects which represent so large a share of human thought be treated lightly as mere collections of shibboleths and signs, as mere accumulations of data, just as we remember how many pounds there are in a ton, or how many inches in a foot? Shall we value them simply for the applications which they may have in the obtaining of food and drink, and in the manufacture of clothing and machinery? Indeed, can we make any so-called 'practical applications' of them without comprehending the main theories on which they are based, and of which the application is only an offshoot?

All valuable theories in science must be, and are, founded on facts and facts only; their adoption has often been the result of the accumulation of a multitude of these, but their comprehension may be brought about by a careful selection of any one series, the members of which are so logically connected in the pupil's mind that the theory must follow as a result of their existence.

The high school, then, should teach the student to reason in any science it undertakes to teach; it should give time enough to it so as to accomplish this end; it should carefully and conscientiously select those facts only which are of fundamental importance in developing the great theories, and it should so connect these facts that the great theories follow as a logical result. By so doing it will develop a thinking human being who can use what he has learned in any emergency, and who has in him the seed of further development. All other methods are false to science, misleading to the pupil, acting as soporifics instead of stimulants. On this line there can be no compromise.

All scientific work should be experimental. We have advanced to the point where this is universally recognized. It is, however, too frequently the custom to introduce experiments solely because they are cheap. This is a grave mistake. The main question should be: Do they teach what is necessary and are they not too complex for beginners? It is folly to attempt the study of a science with a lot of cheap and misleading experimental claptrap. If fundamental experiments can be performed cheaply, so much the better, but if the science is to be properly taught they must be undertaken whether cheap or dear, or if financial considerations render this impossible the science itself should be abandoned in favor of something else. It is the same principle on which some people go shopping—they buy many things that they do not want, simply because they are cheap, and they go without the necessities because they are dear; yet if they would only refrain from the first line of action they might ultimately save enough for the second.

The high school course is preparatory to that of the college, but it can never take the place of the latter. No student, however well prepared, can, in broadening his learning, afford to do without the fundamental work given by men who have, by their own researches, advanced their sciences. Only such men can truly generalize; only such men are able so to paint the scientific picture that the great truths stand out prominently against a background of minor facts and theories; only such men can produce an harmonious whole. It is in the very nature of things that the place of these advanced workers cannot be taken by the high school teachers. They have neither the time nor the opportunity, excepting in rare instances, to take any prominent part in the progress of their especial lines of work. For this reason the secondary school teacher should draw his inspiration from the investigators; he should follow them as leaders, and, in looking for such guidance, should first ask: 'What have they done?' not: 'With what institution are they connected?' It is a fallacy too often heard that the secondary school teacher alone can write for the secondary schools, because 'he understands the needs of the pupils.' True, he may understand how to write a book which will teach easily, but does he understand what are the fundamental principles of his subject? Does he not perhaps delineate what he *thinks* are the fundamental principles, without knowing that they may be either past history, or, worse still, entirely fallacious?

Too often the college teacher is compelled to entirely undo that which the pupil has learned in the high school—to clear the latter's mind of mistaken notions and to completely reconstruct his mental perspective—before the new work can be undertaken with mutual profit. Those who have gone through this trying ordeal realize that it is a far greater task to eliminate false impressions than it is to create new and right ones.

The high school teacher should develop the power of reasoning and exact observation; the college teacher the power of generalizing and the creative faculty; he should strive to teach the student to think in the terms of his science. To do this he must himself be a creator; he himself must have engaged in lines of original thought and investigation; he must be a living spring, not a pail of water. I have heard it said that the best teachers are often those who have never been able to engage in original research. I am inclined to doubt this. Granted, the investigator may not have the power of fluent speech in the same degree as some others, but he has the inspiration; he has the 'point of view;' he is able to feel relationships and connections which the other cannot, and as a consequence is able to place his pupil's learning on a broader and more permanent basis.

Finally, the college is not the place for narrow specialization; in it the scientific student should still be laying his broad foundation, with the understanding that he must also be gaining a clearer view of the sister sciences which are related to and necessary for an understanding of that which he has chosen for his main subject. The college is no more than the high school the place for technical training, for the latter is never developed in its proper form unless its foundations are laid broad and deep, so that they will, without strain, support any superstructure which may be be placed upon them. It is only when this is the case that the uuiversity development can have its proper meaning. The college should bring forth the man *prepared* to specialize, not the man who has, by a too early following of a narrow line, stunted his power of future development. The university should be able to take many things for granted; it should at once be able to devote its time to the growth of the professional biologist, physicist, chemist, mineralogist or geologist; and, while, of course, it cannot lose sight of the fact that at no stage of the scientific career are the related sciences to be neglected, it should, nevertheless, be able to count on training proper and sufficient to fit the student for the original thought and work which must become a part of his being; for, if he wishes to accomplish anything, these habits must be with him through life.

In this way the scientific training of a student becomes a harmonious whole without break, let or hindrancc, from the beginning in the secondary school up to the mature work of the investigator and teacher; for the members are of one race and of one people, forever whole and indivisible.

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THE LACOE COLLECTION IN THE NATIONAL MUSEUM.

IN SCIENCE for July 3, 1896, the late Dr. G. Brown Goode announced the very valuable gift of the 'Lacoe Collection of Fossil Plants.' At that time Mr. R. D. Lacoe, a leading business man of Pittston, Pennsylvania, presented to the U. S. National Museum by far the largest and most valuable collection of Paleozoic plants in America, comparing favorably with the richest collections of the same nature in European museums. Living in a region rich in fossil plants, and noting early in the seventies that no great collections of this kind were accumulating, and also that little or no attention was being given to securing American Paleozoic insects, which are among the rarest of fossils, he quietly set to work gathering material and assisting paleontologists in the study of his collections. The plant collection contains nearly 100,000 specimens and is stored in 1,000 museum drawers and many large exhibition cases. There