SCIENCE.—SUPPLEMENT.

FRIDAY, JUNE 25, 1886.

THE PHYSICAL LABORATORY IN MODERN EDUCATION.[1]

FROM the moment we are born into this world, down to the day when we leave it, we are called upon every moment to exercise our judgment with respect to matters pertaining to our welfare. While nature has supplied us with instincts which take the place of reason in our infancy, and which form the basis of action in very many persons through life, yet more and more as the world progresses, and as we depart from the age of childhood, we are forced to discriminate between right and wrong, between truth and falsehood. No longer can we shelter ourselves behind those in authority over us, but we must come to the front, and each one decide for himself what to believe and how to act in the daily routine and the emergencies of life. This is not given to us as a duty which we can neglect, if we please, but it is that which every man or woman, consciously or unconsciously, must go through with.

Most persons cut this gordian knot, which they cannot untangle, by accepting the opinions which have been taught them, and which appear correct to their particular circle of friends and associates: others take the opposite extreme, and, with intellectual arrogance, seek to build up their opinions and beliefs from the very foundation, individually and alone, without help from others. Intermediate between these two extremes comes the man with full respect for the opinions of those around him, and yet with such discrimination that he sees a chance of error in all, and most of all in himself. He has a longing for the truth, and is willing to test himself, to test others, and to test nature, until he finds it. He has the courage of his opinions when thus carefully formed, and is then, but not till then, willing to stand before the world and proclaim what he considers the truth. Like Galileo and Copernicus, he inaugurates a new era in science, or, like Luther, in the religious belief of mankind. He neither shrinks within himself at the thought of having an opinion of his own, nor yet believes it to be the only one worth considering in the world; he is neither crushed with intellectual humility, nor yet exalted with intellectual pride; he sees that the problems of nature and society can be solved, and yet he knows that this can only come about by the combined intellect of the world acting through ages of time, and that he, though his intellect were that of Newton, can, at best, do very little toward it. Knowing this, he seeks all the aids in his power to ascertain the truth; and if he, through either ambition or love of truth, wishes to impress his opinions on the world, he first takes care to have them correct. Above all, he is willing to abstain from having opinions on subjects of which he knows nothing.

It is the province of modern education to form such a mind, while at the same time giving to it enough knowledge to have a broad outlook over the world of science, art, and letters. Time will not permit me to discuss the subject of education in general, and, indeed, I would be transgressing the principles above laid down if I should attempt it. I shall only call attention, at this present time, to the place of the laboratory in modern education. I have often had a great desire to know the state of mind of the more eminent of mankind before modern science changed the world to its present condition, and exercised its influence on all departments of knowledge and speculation. But I have failed to picture to myself clearly such a mind; while, at the same time, the study of human nature, as it exists at present, shows me much that I suppose to be in common with it. As far as I can see, the unscientific mind differs from the scientific in this, that it is willing to accept and make statements of which it has no clear conception to begin with, and of whose truth it is not assured. It is an irresponsible state of mind without clearness of conception, where the connection between the thought and its object is of the vaguest description. It is the state of mind where opinions are given and accepted without ever being subjected to rigid tests, and it may have some connection with that state of mind where every thing has a personal aspect, and we are guided by feelings rather than reason.

When, by education, we attempt to correct these faults, it is necessary that we have some standard of absolute truth; that we bring the mind in direct contact with it, and let it be convinced of its errors again and again. We may state, like the philosophers who lived before

[1] Address delivered at the tenth anniversary of the Johns Hopkins university.

Galileo, that large bodies fall faster than small ones; but, when we see them strike the ground together, we know that our previous opinion was false, and we learn that even the intellect of an Aristotle may be mistaken. Thus we are taught care in the formation of our opinions, and find that the unguided human mind goes astray almost without fail. We must correct it constantly, and convince it of error over and over again, until it discovers the proper method of reasoning, which will surely accord with the truth in whatever conclusions it may reach. There is, however, danger in this process that the mind may become overcautious, and thus present a weakness when brought in contact with an unscrupulous person, who cares little for truth and a great deal for effect. But if we believe in the maxim that truth will prevail, and consider it the duty of all educated men to aid its progress, the kind of mind which I describe is the proper one to foster by education. Let the student be brought face to face with nature; let him exercise his reason with respect to the simplest physical phenomenon, and then, in the laboratory, put his opinions to the test: the result is invariably humility, for he finds that nature has laws which must be discovered by labor and toil, and not by wild flights of the imagination, and scintillations of so-called genius.

Those who have studied the present state of education in the schools and colleges tell us that most subjects, including the sciences, are taught as an exercise to the memory. I myself have witnessed the melancholy sight, in a fashionable school for young ladies, of those who were born to be intellectual beings reciting page after page from memory, without any effort being made to discover whether they understood the subject or not. There are even many schools, so called, where the subject of physics or natural philosophy itself is taught, without even a class experiment to illustrate the subject and connect the words with ideas. Words — mere words — are taught, and a state of mind far different from that above described is produced. If one were required to find a system of education which would the most surely and certainly disgust the student with any subject, I can conceive of none which would do this more quickly than this method, where he is forced to learn what he does not understand. It is said of the great Faraday that he never could understand any scientific experiment thoroughly until he had not only seen it performed by others, but had performed it himself. Shall we, then, expect children and youth to do what Faraday could not do? A thousand times better never teach the subject at all.

Tastes differ, but we may safely say that every subject of study which is thoroughly understood is a pleasure to the student. The healthy mind as well as the healthy body craves exercise, and the school-room or the lecture-room should be a source of positive enjoyment to those who enter it. Above all, the study of nature, from the magnificent universe, across which light itself, at the rate of 186,000 miles per second, cannot go in less than hundreds of years, down to the atom of which millions are required to build up the smallest microscopic object, should be the most interesting subject brought to the notice of the student.

Some are born blind to the beauties of the world around them, some have their tastes better developed in other directions, and some have minds incapable of ever understanding the simplest natural phenomenon; but there is also a large class of students who have at least ordinary powers and ordinary tastes for scientific pursuits. To train the powers of observation and classification, let them study natural history, not only from books, but from prepared specimens or directly from nature; to give care in experiment, and convince them that nature forgives no error, let them enter the chemical laboratory; to train them in exact and logical powers of reasoning, let them study mathematics: but to combine all this training in one, and exhibit to their minds the most perfect and systematic method of discovering the exact laws of nature, let them study physics and astronomy, where observation, common sense, and mathematics go hand in hand. The object of education is not only to produce a man who *knows*, but one who *does;* who makes his mark in the struggle of life, and succeeds well in whatever he undertakes; who can solve the problems of nature and of humanity as they arise; and who, when, he knows he is right, can boldly convince the world of the fact. Men of action are needed as well as men of thought.

There is no doubt in my mind that this is the point in which much of our modern education fails. Why is it? I answer, that the memory alone is trained, and the reason and judgment are used merely to refer matters to some authority who is considered final, and, worse than all, they are not trained to apply their knowledge constantly. To produce men of action, they must be trained in action. If the languages be studied, they must be made to translate from one language to the other until they have perfect facility in the process. If mathematics be studied, they must work problems, more problems, and problems again, until they have the use of what they know. If they study the sciences, they must enter the laboratory, and stand face to face with nature; they must learn to test their knowledge constant-

ly, and thus see for themselves the sad results of vague speculation; they must learn by direct experiment that there is such a thing in the world as truth, and that their own mind is most liable to error; they must try experiment after experiment, and work problem after problem, until they become men of action, and not of theory.

This, then, is the use of the laboratory in general education, — to train the mind in right modes of thought by constantly bringing it in contact with absolute truth, and to give it a pleasant and profitable exercise, which will call all its powers of reason and imagination into play. Its use in the special training of scientists needs no remark, for it is well known that it is absolutely essential. The only question is, whether the education of specialists in science is worth undertaking at all; and of these I have only to consider natural philosophers or physicists. I might point to the world around me, to the steam-engine, to labor-saving machinery, to the telegraph, to all those inventions which make the present age the 'age of electricity,' and let that be my answer. Nobody could gainsay that the answer would be complete; for all are benefited by these applications of science, and he would be considered absurd who did not recognize their value. These follow in the train of physics, but they are not physics: the cultivation of physics brings them, and always will bring them; for the selfishness of mankind can always be relied upon to turn all things to profit. But in the education pertaining to a university we look for other results. The special physicist trained there must be taught to cultivate his science for its own sake. He must go forth into the world with enthusiasm for it, and try to draw others into an appreciation of it, doing his part to convince the world that the study of nature is one of the most noble of pursuits, that there are other things worthy of the attention of mankind besides the pursuit of wealth. He must push forward, and do what he can, according to his ability, to further the progress of his science.

Thus does the university, from its physical laboratory, send forth into the world the trained physicist to advance his science, and to carry to other colleges and technical schools his enthusiasm and knowledge. Thus the whole country is educated in the subject, and others are taught to devote their lives to its pursuit, while some make the applications to the ordinary pursuits of life that are appreciated by all.

But for myself I value in a scientific mind most of all that love of truth, that care in its pursuit, and that humility of mind, which makes the possibility of error always present more than any other quality. This is the mind which has built up modern science to its present perfection, which has laid one stone upon the other with such care that it to-day offers to the world the most complete monument to human reason. This is the mind which is destined to govern the world in the future, and to solve problems pertaining to politics and humanity as well as to inanimate nature.

It is the only mind which appreciates the imperfections of the human reason, and is thus careful to guard against them. It is the only mind that values the truth as it should be valued, and ignores all personal feeling in its pursuit. And this is the mind the physical laboratory is built to cultivate. HENRY A. ROWLAND.

THE FORMATION OF STRUCTURELESS CHALK BY SEAWEEDS.

CHALK has hitherto been believed to be a deep-sea formation only, made up of a fine ooze or mud at great depths, and undoubtedly, so far as the extensive cretaceous deposits are concerned, the explanation is the correct one; but recent observations by Mr. J. Walther on the chalk-secreting algae of the Mediterranean show that its formation often occurs in shallow water. It has been known for some time that the nullipores were chalk-secreting algae, and that under certain conditions, as in the formation of coral islands, they took more or less part in the production of rock. Where their remains are found in any abundance, chalk formations are readily enough ascribed to their agency, but it is now shown that more or less extensive beds, or rather banks, of wholly structureless chalk, whose origin has been oftentimes enigmatical, may be entirely due to seaweeds.

Mr. Walther observed certain forms (Lithothamnia) in different places in the Gulf of Naples, growing luxuriantly at a depth of from one to three hundred feet below the surface, and traced out the relation between the masses of dead residual matter and the incompletely transformed beds of fossil chalk. These Lithothamniae have a remarkably small proportion of organic material (not more than five or six per cent), nearly the entire substance consisting of mineral matter, chiefly carbonate of lime. The plants reach only the size of one's fist, and do not change their form at death, owing to the small quantity of decaying matter they contain. The living plants secure attachment to the dead ones, forming extensive beds. The numerous stout branches of less than a fourth of an inch in length admit of only small interstices; in slow-growing beds inequalities and shallow depressions may be filled with layers of detritus.

The organic structure disappears to a greater or