THURSDAY, MARCH 10, 1870

SCIENCE EDUCATION IN GERMANY

II. THE POLYTECHNIC SCHOOLS

THE "Polytechnicum" is an institution peculiar to Modern Germany. It has for its object the teaching of all branches of the sciences of experiment and observation, not only in their principles, but in their applications to the industrial arts; these applications not being merely treated as illustrations of science, but regarded as the main subjects for instruction, for the sake of the understanding of which systematic courses on theoretic science are given.

The Polytechnica are altogether independent of the science departments of the Universities, but like these latter the Polytechnica are State institutions, the Professors (ranking generally somewhat below those of the University) are Government servants, and the current expenses are defrayed by State grants.

As a type of this interesting class of Science schools I may cite the two celebrated schools of Carlsruhe and Zurich, beginning with the Carlsruhe school with its 600 students.

In the original programme the school was declared to consist of *one* general and *seven* special departments. The general department, called the *Mathematical*, furnished instruction in mathematics, in natural science, and in modern languages and literature. It was viewed as preparatory to the special schools, and also as adapted for those who proposed to become teachers of mathematics and natural science. The seven special schools were of (1) civil engineering; (2) mechanical engineering; (3) architecture; (4) forestry; (5) manufacturing chemistry; (6) commercial studies; (7) civil service (*Postschule*). This constitution is in the latest programme, so far modified that (1) the general department is no longer treated in form as introductory to the rest, though it still appears to be so virtually; (2) the last two of the special departments enumerated above are omitted, while an agricultural department is added. The schools are, therefore, now seven, viz.:—

	Duration of complete course.
1. Mathematics	2 years
2. Civil Engineering	2½ ,,
3. Mechanical Engineering	2 ,,
4. Architecture	4 ,,
5. Chemistry	— ,,
6. Forestry	3 ,,
7. Agriculture	2½ ,,

The teaching staff consists of twenty-four professors with sixteen assistant lecturers and laboratory assistants. The appliances comprise five laboratories, viz. chemical, physical, mineralogical, and one for forestry and agriculture; a library; and twelve different cabinets or collections. In the department of natural philosophy, as many as 120 students attended the lectures of Professor Wiedemann in the summer semester of 1868. The cabinets are large and well-arranged. In the physical laboratory there were in the above year fourteen students, who went through the course of instruction in groups of four; most of these become teachers of the subjects in *Real-Schulen*; some get important posts in large mechanical workshops.

In Zürich exist both a University and a Polytechnic School; and although the university is a cantonal, and the school a federal institution, they are so far allied that they share one magnificent building, and many students of the university are, at the same time, pupils in the school. The total expense to the State for the maintenance of the Polytechnic School is 12,000*l.* per annum, whilst the original cost of the stately building itself was 160,000*l.* The professors of the two institutions, moreover, work to a certain degree in concert. For instance, Dr. Bolley is Professor of Chemistry in the school, and Dr. Städler, Professor of the same subject in the university. They have each a laboratory; but Professor Städler's is an analytical, and Professor Bolley's a technical laboratory. About 40 students work in the former, and 50 in the latter on an average.

There is less freedom allowed to pupils of the school, as to the classes to be attended, than is customary at the university. Definite courses are laid down; but relaxations are freely granted.

The most important department of this Polytechnic School is that of mathematics and engineering; there are also departments of forestry and agriculture, and an important department for teachers—a sort of technological seminary.

The Professor of Technical or Applied Chemistry, Dr. Bolley, lectures three or four times weekly throughout the session. He makes four or five sub-divisions of his course;—thus he lectures on the Chemistry of Colour; of Heating and Lighting; of Materials of Nourishment; and of Agriculture. Before entering this class, the student is required to have attended a course of theoretical lectures on chemistry, and an elementary experimental course.

Dr. Zeuner, the Professor of Engineering, gives about fifty or sixty lectures yearly on the Mechanical Theory of Heat; and he lectures six times a week for two semesters, on the Theory of Machines. The character of his courses is very high and rigorous; he insists on a knowledge of the differential calculus as a condition of entering his classes, and he remarked to the writer on the generally inadequate mathematical preparation of English students of engineering, mentioning his conviction that Professor Rankine, for whose works he expressed an unbounded admiration, must find the sphere of his efficiency as a teacher seriously limited by reason of the want of due preparation on the part of his students.

The following extracts from the prospectus of the lectures in the engineering department of the Zürich school, show how much more complete is the scheme of instruction there than has at present been found possible in England.

B. *Department of Civil Engineering.* (Duration of course, 3½ years.)

1st year.—Differential and Integral Calculus. Descriptive Geometry. Principles of Construction. Practice in Construction. Drawing. Experimental Physics. Experimental Chemistry.

2nd year.—Differential Equations. Technical Mechanics. Geometry of three dimensions. Perspective. Technical Geology. Topography. Drawing. Descriptive Mechanical Construction. Surveying.

3rd year.—Theoretical Mechanical Construction. Astronomy. Geodesy. Construction of Iron Bridges, Railways, and Iron Roofs. Drawing.

In addition to these courses there are similarly extensive programmes for (A) the department of Architecture, and (C) the department of Mechanical Engineering. The number of regular students in the year 1867, was in these subjects (A) department of Architecture, 33; (B) department of Civil Engineering, 103; (C) department of Mechanical Engineering, 87.

That the Polytechnic system of science education finds favour, at any rate, with the German State Governments, and therefore probably also with the people, is apparent from the fact that large institutions of the kind have just been built in Prussia (at Aix-la-Chapelle), in Austria (at Vienna), and in Bavaria (at Munich). In this latter city no less a sum than 125,000*l.* has been expended on the building of the new Polytechnicum, erected in a very costly style of architecture, and covering five acres of ground, whilst distinguished men from all parts of Germany have been called to fill the newly-founded professorships. The cost of the buildings at both Vienna and Aix-la-Chapelle will probably not be far short of the above amount, and it must be remembered that labour and material are very much (probably one-half) lower in Germany than with us. The expenses of education at the Polytechnica are very small; at Carlsruhe attendance on the regular courses of lectures costs 5*l.* 10*s.* for the session of nine months; the fee for chemical laboratory practice for the same length of time is 3*l.* 15*s.* to regular students, and 5*l.* to occasional students. At Zürich the fees are even lower, as any of the regular courses of the distinct departments or schools can be attended for the payment of 109 francs, or about 4*l.* 4*s.* for the session of nine months.

The age for entrance into the Polytechnic Schools is one year younger than that for the German Universities, viz. seventeen: the duration for study is the same, three years. Here, too, evidence of fitness is vigorously exacted of those who propose to enter as *regular students*, in the shape of an adequate school certificate, either from a gymnasium, a real-gymnasium, or a *Real-Schule*; or, in default of that, an entrance examination must be passed. A much higher mathematical preparation is demanded than is needed for entering the University, a knowledge at least up to, and in some schools including, the differential calculus being required. Persons of all ages, however, and not possessing such qualification, are admitted freely and without examination, as *occasional* students in the several departments. Many of these occasional students are often poorly prepared; but it is considered that the gain to such auditors, and to society through them, is great; and that, whatever tendency might arise from this practice towards the lowering of the standard of instruction could be guarded against by rigidly keeping up the standard of admission for regular students.

To many of the Polytechnica is attached a preliminary school, in which those who are not ripe for the full studies of the Polytechnicum can supply their deficiencies. The age for entrance to this *Vorschule* is sixteen.

In all the Polytechnica with which the writer is acquainted, it is the schools of civil and mechanical engineering, building construction, and architecture which really flourish. These departments of applied science are not represented in the German university system, whereas the study of chemistry in its various divisions, and of mechanics and physics in their numerous branches, forms a portion of every university course. Indeed, as a rule, the lectures delivered in the Polytechnic Schools on chemistry and physics differ very slightly, if at all, in character and scope from those which the University professor delivers. The fact is that the teaching of special technical chemistry in the Polytechnica has been found to be impossible. All that can be done in any school is, in the first place, to teach the groundwork of the science without regard to its applications, and then to point out the scientific principles upon which certain technical processes depend. No system of theoretical school instruction will fit a man to be a dyer or a calico-printer, or even a chemical manufacturer. These arts can only be learnt by practice on the large basis of practical experience, and all that Polytechnic Schools can do is to prepare the ground for a proper reception of that practical experience by a sound training in scientific principles.* This scientific training is, however, just as much the special work of the University as of the Polytechnicum, and there appears to be no valid reason for the separate existence, often side by side in one town, of a University and a Polytechnic School. On many grounds the absorption of the Polytechnicum by the University appears advisable. In the first place there is room to fear that a due supply of thoroughly good teachers, especially in science—at least in the higher positions—cannot be secured for institutions perpetually growing in number, while, on the other hand, a great waste of power is caused where such institutions exist side by side, as many of the professorships, being common to Universities and Polytechnic Schools, are thus twice represented.

Again, serious harm must come from the tendency which this separation of the Polytechnic School from the University has to foster the narrow one-sidedness already so strong in the extreme partisans of the one and the other group of studies. The Universities would suffer by the weakening in them of those branches of pure and applied science which have always been and must continue to be studied there. The Polytechnic schools would suffer (and already do suffer) from the tendency, thus encouraged, to neglect the *educational* aspects of science in considering its practical applications. How great the gain has been to the branches of the liberal arts and sciences from their alliance in Universities, the history of Universities from their first foundation abundantly shows: and it is difficult to see any sufficient reason why the applied sciences, such as Engineering, in their professional aspect should not have their proper place in the organisation of the University, exactly as Theology, Law, and Medicine have long had their place, to the great advantage both of these studies themselves and of the non-professional studies with which they have been brought into contact.

Signs are already observable in Germany, according to the highest authorities, that the zeal for teaching science in its application to the practical arts is encroaching on the domain of science proper, and that science will be deteriorated without, at the same time, industry being advanced. The true work of institutions,

* This is clearly admitted in certain cases by the Polytechnic authorities themselves. Thus I find in the regulations of the Carlsruhe Agricultural School the following words printed in large type:—"This school is concerned with the cultivation of the mind of the student, not with learning the technical operations of agriculture."

founded with the special aim of fostering the industrial arts, should be to insist on teaching *principles* systematically, and not in their isolated applications. To treat of the applications of the science is, of course, necessary, even for the sake of science itself; and under certain circumstances, some of these applications may wisely be dwelt on more than others; but this is quite a different thing from pretending to teach as *science* detached *fragments* of science in their application to this or that art.

The following extract from a well-known essay by Liebig, written so long ago as 1840, clearly shows that his views on this question coincide with those above expressed:—

"The teaching of science in the laboratories of the Trade—and Polytechnic—Schools is, in most places (in Prussia), very deficient. A system of true scientific instruction should fit a student for each and every possible application of science; for these applications become easy, and follow as a matter of course, from a knowledge of scientific principles. Nothing is more deleterious or dangerous than when utilitarianism is made the foundation of a system of tuition in a school, or when institutions, whose true aim ought to be experimental instruction in scientific principles, are employed to convert mere children into soap-boilers, brandy-distillers, or sulphuric acid makers. All this entirely destroys the true purpose of the institution.

"I have found, in all those attending my laboratory who intended to pursue a technical course of study, a general predisposition to devote themselves to some branch of applied chemistry. It is only with feelings of fear and trepidation that they consent to follow my advice, and give up the time they thus waste on mere drudgery to making themselves acquainted with the methods by which pure scientific problems are soluble, and by which alone they can be solved. . . . . There are many of my pupils, now at the head of many departments of manufacturing industry, who, having had no previous acquaintance with the processes, were in half an hour perfectly *au fait* with all the details of the manufacture, whilst in a short time they saw and introduced all sorts of necessary reforms and improvements. This power they had gained by being accustomed in their laboratory work to obtain the most accurate and precise knowledge of all the substances which came into their hands in their work; they had to learn the conditions necessary for avoiding errors, they investigated the properties of the products of decomposition formed, and thus became acquainted with the sources of error, with the means of avoiding losses; they were able to improve their apparatus, and to amend their processes. All this can never be learnt when the work is conducted according to cut-and-dry methods."

There are, no doubt, certain obstacles in the way of the proposed amalgamation in Germany; but in the old English Universities, and in the science colleges which we hope soon to see established in various parts of England, the difficulty would not arise at all. Apart from questions of tradition and historical routine, there can be no reason why students of applied science, led by their probable destination to manufacturing industry, should not study systematic science in the same class-rooms with students of the same subject who may have other aims: and if such students require minute practical and experimental instruction, there is no reason why they should not obtain this in physical and mechanical, as they do already in chemical, laboratories. In such a technical department, future teachers of science and leaders of manufacturing industry would be trained in the application of science to the most important branches of art and manufacture—so far, that is, as these are fit subjects for academic treatment; so far as they are not, they must be left to the workshop.

H. E. ROSCOE

VON SCHLICHT ON FORAMINIFERA

Die Foraminiferen des Septarienthones von Pietzpuhl. By E. von Schlicht. 4to. With 38 lithographic plates. (Berlin, 1870. London: Williams and Norgate.)

SINCE the appearance of D'Orbigny's "Foraminifères Fossiles du Bassin Tertiaire de Vienne," no work has been issued on the Foraminifera in their geological or palæontological relations, with pretensions at all corresponding to those of the newly-published monograph, the title of which stands at the head of the present article. We do not use the word *pretensions* in an offensive sense, for the author is careful to apprise his readers of the limitations of the treatise; but rather to indicate the sort of impression produced by the dimensions of the book and its profuse illustration. A quarto volume containing, in addition to the letter-press, thirty-eight large plates devoted to the Foraminifera of a small division of the Tertiary system of North Germany, and confined to a very limited district, or, as we might put it, 1,192 drawings of microscopic shells from the clay of a single brickyard, ought to show in its results a very evident *raison d'être* to save it from the imputation of labour thrown away. We need not require the expression of new or startling philosophical views to bring such a work within the scope of things worth doing; but we may fairly expect from so large an expenditure of labour and cost, some real and definite addition to our scientific knowledge. Whilst a smaller book might pass unnoticed, or at least without critical examination, one like this cannot escape without an inquiry as to what it contains of novelty, either in observation or theory,—in facts or their arrangement; and on the reply dictated by a patient study of its contents, the verdict as to its value must depend. To frame an answer to these questions which will serve to give an idea of the work, it will be necessary to offer a few preliminary observations and to epitomise the labours of previous observers in the same field.

In the Tertiary system of Belgium, and Northern and Central Germany, there occurs a thick bed of clay, containing nodules of argillaceous limestone, with radiating cracks or fissures in their interior, which have become filled with calc-spar. These nodules are termed "septaria," and they are regarded as sufficiently characteristic of the deposit to give it a name, though possibly a somewhat indefinite one. As used by German authors, the term "Septarienthon" includes the Rupelian clays of Rupelmonde and Boom, near Antwerp, the brick-clays of the neighbourhood of Berlin, together with similar beds in the valleys of the Maine and Elbe, and in many other localities between the Baltic and the centre of Germany. These beds are of Lower Miocene or Upper Eocene age, and belong to a group of transition strata, associated by