APPENDIX C. (Page 259.)

A Plan for a Polytechnic School in Boston.

1846.

A school of practical science completely organized should, I conceive, embrace full courses of instruction in all the principles of physical truth having direct relation to the art of constructing machinery, the application of motive power, manufactures, mechanical and chemical, the art of engraving with electrotype and photography, mineral exploration and mining, chemical analysis, engineering, locomotion and agriculture. It would require two departments.

First, one in which by courses of lectures, amply illustrated, a broad and solid foundation should be laid in general physics, including especially the mechanics of solids, liquids and airs, and the laws of heat, electricity, magnetism and light, and in the chemistry of the more important inorganic and organic principles. Without a sufficient groundwork of this kind in general physical laws, it is obvious that the details of applied science would have but little attraction, and being but vaguely apprehended would convey very little valuable instruction. This department would, I think, give employment to two instructors, dividing the various topics between them as might be found convenient, and perhaps at the same time lecturing on some of the applied branches, as portions of the chemical arts, the strength of materials, motive powers, the steam engine, or any of the practical subjects capable of being taught in lectures with the aid of experiments, models and diagrams.

The other, and entirely practical department, would embrace instruction in chemical manipulation and the analysis of chemical products, ores, metals and other materials used in the arts, as well as of soils and manures. *Second*, — A course of practical, elementary mathematics, and *Third*, — full instruction in drawing and modelling. This branch should also include special courses of teaching in architecture, engineering and the various branches of the arts not treated of in the first department. This second division of the school besides employing two or three tutors, or sub-professors, to give personal instruction in the laboratory, workshop or room for drawing, might yearly invite the aid of eminent practical men to give courses of lectures on the various branches of applied science not otherwise provided for, or it might engage the services of such permanently for the more important subjects after a trial of the practical benefits of their collaboration. A scheme of this kind begun with two professors in the scientific department and two subordinate instructors in the other, under the direction of the former, would, I am certain, prove so signally successful as ultimately to require its expansion into a polytechnic college on the most ample scale, in which, along with all the subjects above referred to, would be embraced full courses in elementary mathematics and instruction, perhaps, in the French and German languages. In a word, I doubt not that such a nucleus-school would, with the growth of this active and knowledge-seeking community, finally expand into a great institution comprehending the whole field of physical science and the arts with the auxiliary branches of the mathematics and modern languages, and would soon overtop the universities of the land in the accuracy and the extent of its teachings in all branches of positive knowledge.

According to my present notions of expediency and usefulness, the two professors in the scientific, or more properly the mixed department, should so frame their general courses of lectures as to make them acceptable and useful to the public at large, and thus furnish annual courses on general physics, chemistry and geology, which might draw all the lovers of knowledge of both sexes to the halls of the Institute, whether they proposed or not, continuing their studies in the other and directly practical branches of the Institution. This, of course, should be, as it very well could be, done without any sacrifice of the exactness of scientific or practical demonstration to mere popular effect. We know how successful have been the courses in the Royal Institute of London, where Brandt, Faraday and Wheatstone have for years been the chief instructors of practical science. The school in Boston, too, might well adopt the valuable practice of the Royal Institute of having stated lectures for diffusing a knowledge of important new inventions in the arts, and discourses in physical science. By so doing besides the general benefit of an early communication of valuable truths, often so important to practical men, there would arise the special advantage to the Institute itself of a reputation for being foremost in the appreciation and promulgation of such useful knowledge, and this would give it a strong claim upon the respect and affection of the public.[1]

The true and only practicable object of a polytechnic school is, as I conceive, the teaching, not of the minute details and manipulations of the arts, which can be done only in the workshop, but the inculcation of those scientific principles which form the basis and explanation of them, and along with this a full and methodical review of all their leading processes and operations in connection with physical laws. When thus instructed in applied science, the mechanician, chemist, manufacturer or engineer clearly comprehends the agencies of the materials and instruments with which he works, and is, therefore, saved from the

[1] The six paragraphs (and one sentence) next following have already been given on pp. 260–262, but are here introduced in their proper connection.

disasters of blind experiment, is guided securely because understandingly in a profitable routine, and is directed in the contrivance of new and more efficient combinations. We cannot but believe that, with a proper training in science, the host of unprofitable inventors, living within the last half century, would have contributed innumerable valuable aids to human industry, and advanced the arts to a far higher stage of improvement than they have yet attained. Of this no stronger argument could be asked than a glance at the encumbered cases of the Patent Office in Washington.

Indeed, the unexampled progress, both here and in Europe, of every branch of the arts for the last fifty years is but the result of that general diffusion of a better knowledge of physical laws which has flowed from the researches and teachings of men specially devoted to natural science; bearing in mind too, how few of the almost countless products of ingenuity, even in these times, are of real and permanent value and how immense the number of utterly barren inventions, the laboured contrivances of acute but undirected or misguided mind.

Among practical pursuits there are, perhaps, none whose dependence upon the determination of physical science is more generally recognized than those of the machinist, the engineer and the architect. Yet even in these professions, while all admit that many of the details are but immediate applications of the leading laws of mechanical philosophy, how few have formed a just conception of the variety and extent of science they involve.

In the first place, the materials used in construction must be studied in their more important chemical and mechanical relations. Rules must be applied for computing the strength of beams and columns of timber and metal of various shapes and dimensions, and placed in various attitudes within buildings or machinery, and these cannot be safely used without a knowledge of the experimental data and mechanical principles from which they have been deduced. So likewise in resolving the often recurring problem of the distribution of forces to the several parts of a structure as dependent on the arrangement of the parts and the position of the load, or other pressure, the necessity for scientific principles is immediate and unavoidable. Of the durability of the materials employed in masonry, it is evident that no confident judgment can be formed without a knowledge of their composition and of the chemical action to which they are liable from air, water and thermal changes. The machinist should understand all the principles of equilibrium and of the composition of forces; in other words, the general doctrines of statics and dynamics, those of friction and resisting forces generally, the mode of operation of the various motive powers of which his machines are to be, as it were, conductors, and the methods of computing the relation between the force applied and the useful effect obtained, or in other words the economical value of the combination.

The engineer of roads and canals with ample knowledge in all these particulars should further have a good acquaintance with the mineral and geological character of the region in which he operates, should know when to interpret the appearances on the surface either as an encouragement or warning in directing his locations; should be prepared to judge of the value of the rocky materials he encounters in building an embankment, and should be qualified to form an estimate of the relative advantages of different districts as influenced by the extent and nature of these mineral products.

Instruction in all these and other kindred particulars, essential as it is to the fullest success in the pursuits referred to, involves, it will be seen, no insignificant acquaintance with some of the leading branches of mechanical and even geological and chemical science.

If we turn now to the manufacturing arts, we shall find an equal and, in many cases, even more urgent demand for scientific guidance.[1] Beginning with those connected with metallurgy, we see in the various processes by which iron, copper, lead, zinc, silver and other metals are obtained from their ores the most direct application of chemical and mechanical science. The form and materials of the furnace, the character of the fuel and flame, the preparatory processes of roasting, or washing, the due modification of the procedures according to the nature and proportion of the foreign substances present, with numerous other practical details in the various stages of the operation, are only intelligible through the medium of scientific principles, and are most likely to be successfully pursued, or improved, when these principles are clearly understood and habitually recurred to. So also in the fabrication of steel and the mixed metals, such as brass, bronze and tinned iron, and in casting, rolling, wire drawing and other mechanical and chemical processes of the same kind, the truths of science have many important applications, and are capable of affording suggestions of high utility. In gilding, plating and the processes of electrotype, in engraving in all its branches, including lithography, zincography and the various departments of photographic art, we see the most varied agencies of physical laws, involving the mechanical properties of materials, their relations to solvents, and the powers of heat and light. In the fabrication of pottery and porcelain in all the varieties, and in the colouring and painting of both these classes of products, every step is but an application of some well-known scientific principle.

Of the refining of sugar and the manufacturing of alum, copperas, white lead, bleaching salts, the acids, and a hundred other important chemical products, it is needless to say more than that the processes they involve are but the vast practical enlargement of the common experiments

[1] See p. 262. The letter there begun is here continued.

of the laboratory and lecture-room. The production of illuminating gas from coal, fats or rosin, and the processes for its purification, the manufacture of stearine, wood vinegar, and all the whole variety of soaps, the purification of oils, the making of cements and varnishes, the arts of tanning, bleaching, dyeing and calico printing, with a hundred others extensively practised at the present day, are either the direct results of modern scientific research, or are largely indebted to it for those experiments in mechanical and chemical details which have bestowed on many of them a more than hundred-fold productiveness. So clearly indeed has the importance of a scientific guidance been proved in some of these arts, that we now in many cases see them claiming the superintendence of skilful chemists to direct their daily operations, and I need not add that the fruits of this happy union of science and art are nowhere better exemplified than in the dyeing and printing works for which Lowell has been so celebrated.

In the various forms of mechanism devoted to spinning and weaving in all their branches, in mill work of almost endless variety, in the steam engine, as applied to stationary or locomotive uses, in water wheels, turbines, propellers and the innumerable forms of hydraulic and hydro-pneumatic machinery, we have almost numberless applications of the laws of mechanics, which those only who clearly understand can guide or improve to the best advantage.

In the business of mining in all departments, including that of exploration on the surface and by borings, every important step calls for the suggestions of geology, chemistry and mechanical science.

To close this long but still incomplete catalogue of illustrations, we may safely affirm that there is no branch of practical industry, whether in the arts of construction, manufactures or agriculture, which is not capable of being better practised, and even of being improved in its processes, through the knowledge of its connections with physical truths and laws, and therefore we would add that there is no class of operatives to whom the teaching of science may not become of direct and substantial utility and material usefulness. It would, I think, be especially adapted to fulfil another, and in some respects a higher purpose by leading the thoughts of the practical student into those wide and elevated regions of reflection to which the study of Nature's laws never fails to conduct the mind. Thus linking the daily details of his profession with the grander physical agencies around him, and with much of what is agreeable and ennobling in the contemplation of external things, it would insensibly elevate and refine his character and contribute to the cheerfulness as it aided the efficiency of his labours. In this respect it is, I think, demonstrated that physical studies are better capable of being useful to the operative classes than the study of literature or morals, because their truths are more readily and eagerly seized upon by such minds and form the strong staple of practical usefulness thus firmly infixed. It is easy to extend the golden chain of relations until these may embrace every realm of nature and of thought.

A polytechnic school, therefore, duly organized, has in view an object of the utmost practical value, and one which in such a community as that of Boston could not fail of being realized in the amplest degree.