REMARKS

ON

ELEMENTARY EDUCATION

IN SCIENCE.

AN INTRODUCTORY LECTURE,

DELIVERED AT THE OPENING

OF THE

CLASSES OF MATHEMATICS, PHYSICS, AND CHEMISTRY,

IN THE

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Two years have now elapsed since the first lecture was delivered within the walls of this institution—two years, which, independently of the rise of an University in the metropolis, have given birth to events which will render them remarkable in the history of education. Already we see similar establishments in process of completion, and may rationally prophesy that no long time will elapse before every considerable town in this country will have taken measures to bring home to its inhabitants those facilities for the acquirement of the higher branches of knowledge, which have hitherto fallen to the lot of capital cities only.

But even this is not the most singular feature of the times. The spirit of improvement has ended where she should have begun, by laying her hand upon the systems of preparatory education. Although the notion that all useful knowledge was to be acquired from the study of the learned languages has been some time extinct, it is only now that it begins to be admitted and acted upon, that habits of inquiry and of correct judgment are more useful than any knowledge of facts, however extensive, and that literature and science are to the young mind, not the end of its education, so much as the means of promoting the above-mentioned objects.

It has fallen to me to open, by this preliminary lecture, the classes of elementary science, viz. Mathematics and Natural Philosophy, including Physics, commonly so called, and Chemistry. It would be unnecessary and absurd to repeat, year after year, an eulogium upon these sciences. If there be any one who thinks that they are unnecessary as a part of education, let him carry his opinion into the world, and see what reception it will meet with. I assume it for granted, that every well-educated person should have a general acquaintance with all three. Their utility is undisputed, and the common sense of the public is leading them fast to an entire agreement with the opinion of Locke, that "it is a shame for them that have time and the means to attain knowledge, to want any helps or assistance for the improvement of their understandings, that are to be got." Were these sciences desirable only on account of the knowledge directly obtained from them, I could but recommend them as objects of professional study; but while they are recognized as opening new paths to the intellect, as furnishing the reason with new tools for its operations, and new weapons for its defence, I may well be excused from devoting this lecture to the enumeration of any advantages which are to be derived from them, whether in general or professional education. I shall therefore pass to the consideration of the most efficacious methods of preparing the mind for the successful study of science in general. While the improvement in early education, to which I have alluded, is introducing, to a greater extent, the study of its elements, this discussion is of no small importance.

The studies now under consideration have always laboured under a disadvantage from which those of language have been free. Every child acquires one tongue before any formal education commences: this gives the means of illustrating all peculiarities incident to the rest. A form of expression which would otherwise have conveyed no idea, often presents no obstacle to the student's progress, because he finds similar difficulties in his mother tongue, or what would have been such, had not a habit, formed with the earliest dawn of reason, fixed in his mind the phrase and its corresponding idea. The case is not the same in the study of the sciences. Here both the subject to be followed, the terms to be employed, and the manner of proceeding, are new and strange to the young student, and though his own observation must have furnished him, in some degree, with the ideas on which he is to build, yet since no pains have usually been taken to ensure the accuracy or closeness of thought which is necessary, and of which even a child is capable, the consequence is that in entering upon these studies, he is saddled, when his education is more than half completed, with the irksome and difficult task of acquiring new habits of mind.

Before proceeding to inquire how these difficulties may be most effectually overcome, it will be well to remind you that there is only one way in which can be gained those preliminary notions which are necessary in every branch of education.

It is an assertion which is amply borne out by observation, that all human knowledge, of what kind soever, is based upon experiment. Nevertheless, the proposition is one, which at first hearing is somewhat repugnant to received ideas. What, it may be asked, are the mathematics, of which it is the boast that they demonstrate their conclusions infallibly and without any possibility of error—which are called the pure sciences, because they appear to be mixed up with no considerations directly drawn from matter—which we may conceive to flourish without even supposing the existence of any materials on which to try their results? Are these sciences founded on experiment as much as the theories of gravitation or electricity? Most unquestionably they are. The reason why a contrary notion prevails is that the experiments on which the mathematics are founded do not require laborious research, expensive apparatus, or even the intellect of mature age. They are such as no person who is in the possession of the senses of sight and touch can avoid making continually. They form part of the occupation of every child from the time when the development of its ideas commences. They are readily made; their results are easily retained; and so simple are the last in their nature, that it would have been thought childish to put them into words, had it not become necessary to embody them as the principles and groundwork of the mathematical sciences. The fact is that the terms observation and experiment are closely connected. The first is the faculty of the mind by which the second is conducted, and all the results of observation are so many experiments, whether they are derived by the senses alone, or by the assistance of the telescope or the thermometer.

For example, we learn to distinguish by the sight and touch that which we call a straight line. If any proof were necessary that our ideas on this subject are derived from observation alone, it would be found in the impossibility of defining this term. If any one were to ask me what is meant by the word, I could only answer by referring him to some visible object. By the evidence of our senses, and by no other means, we find that a straight line is such that two of this species can only coincide or meet in one point. The moment they are made to coincide or meet in two points, they become one and the same straight line. Again, suppose a straight line drawn and a point taken without it. Through this point let any other straight lines be drawn in all directions. We can demonstrate that there is one of these straight lines which will never meet the first line, though ever so far produced or lengthened in either direction. But it is to experiment or observation that we are indebted for the knowledge of the fact, that there is ONLY one straight line which is in this predicament, since no demonstration of this assertion has ever been given.

These propositions are the groundwork of geometry, and may fairly be said to be derived in the same manner as the results obtained from the most complicated apparatus; the difference being, that they are observations which we all must have made so often and so early, that we forget the time when we first gathered information from them.

I do not know whether I shall not be considered as pushing this assertion to the verge of paradox when I maintain that our first ideas on the subject of number spring from the same source. The notions of one, or of more than one, are not only obtained from visible and tangible objects, but all the first questions of arithmetic are performed by their assistance. So little do the operations of the mind, unassisted by daily experience and repetition of numerous objects, assist in giving extended ideas of numeration, that those nations whose social wants do not demand large numbers, never acquire the ideas of them. We are acquainted with several tribes who cannot reckon as far as one hundred, and one is mentioned which has no names for numbers beyond five. But whatever may be the opinions upon this subject, this much is certain, that children do constantly resort to the use of some tangible objects, that is, to experiment, to acquire the first notions of number, and to work the first questions of arithmetic.

With regard to Natural Philosophy and Chemistry, I need hardly say, that from experiment, and experiment only, our first knowledge of these sciences is derived. Far from there being any tendency to mistake in this point, the costliness and unusual nature of the apparatus employed, the time and skill required for many of the processes, and, above all, the interesting and popular nature of the results, lead many who are unacquainted with the real state of the case to suppose that these branches of knowledge are wholly dependent upon experiment, and not at all upon reasoning and demonstration. Thus, while, in the notions usually entertained of the mathematics, their difficulties are magnified by the supposition that all is exertion of the intellect, and that the evidence of the senses goes for nothing; on the other hand, the physical sciences, and especially chemistry, are supposed to consist in the exhibition of a series of striking and curious results, unconnected by any train of reasoning:—a notion which, if true, would place them, as a discipline of the mind, in no higher rank than the tricks of a juggler, however useful they might be in their application to the arts of life.

I now proceed to apply these observations to the early study of these sciences, or of preliminary matters connected with them. It would be worse than useless to attempt to teach them to the youngest students in all their extent and rigour. But it does not therefore follow that no pains are to be taken to prepare the way for this knowledge, and to render its acquisition more easy, more interesting, and more accurate. In what way this is to be done lies the question which I propose to discuss.

A young person seizes an idea more readily, and applies it with more facility, when a distinct appellation is given to it. It is not that he has actually acquired knowledge by naming that which was already in his mind, but that he has rendered what he possesses available for the acquisition of more. He has thereby fixed upon it the stamp which will enable it to pass from himself to others, and with interest from others to himself again. He can now form other combinations of ideas, communicate new difficulties, and receive new explanations. Every one must recollect how hard he found it at one time to express what he wished to say when it had any reference to form or shape. Many can remember when their whole geometrical nomenclature consisted in calling a figure which had corners *square*, and one without them *round*, the last term applying equally to the figure of the earth and to that of the wheel of a carriage. Such confusion is no trifling disadvantage. It is a hindrance both to the teacher and the learner. To remedy it, early and correct attention should be given to the meaning of scientific terms. There is no reason whatever why the names angle, parallelogram, circle, rectangle, plane, &c., should not be as familiar, and convey as distinct ideas, as the words long, short, or heavy. The same remark extends also to the terms used in physical science. A child might be made to understand, and to acquire new ideas by understanding, the distinction between such words as fluid and liquid, force and resistance, &c. He could receive and retain more correct notions than are usually given on such expressions as pressure, attraction, friction, &c. In chemistry, he might be taught the use of common terms with more reference to the usual classification of bodies. He would thus come to the study of the sciences with a large stock of preliminary ideas, and with no incorrect notions to alter, arising from the vague and confused use of names. I may appear to some to have been trifling, in entering into such detail, but only those who have taught can know how much depends on the accurate knowledge of simple words, and how effectually the pupil's progress is retarded by the evil for which I have been suggesting the remedy.

Again, the observations which are made in early age, though sufficiently conclusive as to the facts they embrace, never exhibit results in an accurate form, and indeed are little conversant in ideas in which proportion or measurement of any kind are involved. The power of comparing or estimating relations of magnitude is one which shows itself much later than those which we have already noticed, if indeed it would be developed at all, in the greater part of mankind, without the aid of instruction. An assertion which expresses a positive fact, if it be simple, is easily confirmed or refuted: one which implies the comparison of two things of the same sort requires more attention, more knowledge, and more previous habitude of thinking. Thus, for example, no one, however young, will, when the proposition is named to him even for the first time, conceive himself not to have known that two different straight lines can meet only in one point. He will, even if ignorant to this extent before, find within himself such a readiness to assent to the axiom, as he can conceive to arise from nothing but previous knowledge. But the assertion that two sides of a triangle are greater than the third, is one which will require a little more consideration to make it evident to the senses;

that the exterior angle of every triangle is greater than either of the interior and opposite angles, will probably appear doubtful; while, that this exterior angle is exactly equal to the two interior angles, will appear to have no evidence at all. Yet all these propositions might, by a little management, be made so apparent to the senses as to require no further demonstration, as far as moral certainty is concerned. Had no proof of them existed, they might have been received as axioms or first principles; and we may venture to say, that had such been the case, no more objection would have been raised to them at this day, than is experienced by the unproved proposition alluded to in the former part of this lecture, which is in effect the same as the last axiom of Euclid. Perhaps at one time these and many such propositions were viewed in this light. The proverb says, that Rome was not built in a day, and we know that there was a Rome of huts and cabins, which preceded the city of palaces. I could as easily conceive, that the first essay of savages in the art of building would be a magnificent castle, with vaulted roofs and winding staircases, as that the first geometers imagined that there even existed such a connexion between their several propositions as would make one an infallible consequence of another. It is more likely that actual measurement was at one time the only method of discovery or verification; that by these means a large mass of undoubted truths was collected; that accident or more attentive consideration first discovered the connexion between two or more propositions; that men of superior minds, thus drawn to a new view of the subject, began to entertain the suspicion that these empirical truths were the links of one chain, the connexion of which might be traced by reasoning; and that they ultimately succeeded in reducing the whole to the form in which it appears in the immortal work of Euclid. The traditions of the history of the sciences, imperfect as they are, yet bear out this supposition in several points. This early history exhibits in a remarkable manner the same succession of errors, the same course of imperfections and redundancies, which mark the progress of a young student in our days, and should be studied by all who desire to qualify themselves for the task of instructing others.

When we come to consider the subject of arithmetic, we shall find that the results derived from simple observation are less, both in number and importance. Not only is the science itself less striking than that of geometry, but we are not at an early age so conversant with the objects of the former as of the latter. Nevertheless, by drawing the attention of the young to the phenomena, if I may so call them, of numbers, many useful results may be exhibited, which will furnish new and remarkable ideas; and while they show that the science of arithmetic is not what it is usually considered by young people, the extreme of dulness and dryness, will exercise the mind in one of the most useful faculties which it possesses, that of generalising by induction. As an example, let any successive odd numbers, beginning from unity, be added together, the result will always be a square number, that is, one which is formed by multiplying a number by itself. This proposition is usually reserved for the student who has made some progress in algebra; but there is no reason why it should not be established in the mind more early by observation and induction. Many such facts, not only curious and pleasing in themselves, but connected closely with various phenomena of natural philosophy, as is the one just noticed, might be made known at an early age, and their acquisition would lighten the labour of the student in commencing algebra in two ways, since a previous knowledge of such points would render interesting a study, which is usually considered the driest part of mathematics, and the habits of calculation so formed, would lighten the drudgery which is inseparable from its preliminary operations.

The elementary propositions of natural philosophy, and even those of chemistry, are now considered as calculated for the understandings of the youngest students. Many of their simplest truths come into the mind as early as the first principles of geometry, which have fallen under our notice. But here the same remark occurs which I have already had occasion to make. Prominent and absolute facts are seized and recollected, while those which imply comparison or relation excite no curiosity. Thus while each one observes that a stone falls more quickly in the second instant of its descent than in the first, few inquire how much more quickly, or what relation the space described in the second instant bears to that in the first. The general fact connected with all machines, that a small weight is by the disposition of their parts made to balance a larger one, excites attention, while the explanation of the numerical law is viewed with indifference. It is this disposition which, passing unnoticed in the child, lays the foundation of superficial and smattering habits in the man, and brings shame upon what are nevertheless most justly called the improvements in education. It has been objected, and with truth, that the extensions of elementary instruction have not had that tendency to promote real and accurate knowledge which their supporters claim for them. A triumphant answer will never be given to this assertion as long as it is considered sufficient to fill the young mind with pleasing facts stripped of their rigorous form, and therefore incapable of leading to any consequences. Yet who can wonder that, as far as the physical sciences are concerned, such habits should prevail, when so many are allowed in their youth to skim the surface of natural philosophy, to abstract only what is pleasing and prominent, to fix their attention on simple facts, without being led to observe the actual relations which prevail among them, the laws, as they are called, which regulate the phenomena, by the observation and verification of which alone real instruction is to be derived from experiment. Strip the results of physics of their accurate and numerical character, let them be any thing else but exercises of the powers of comparison and measurement, and a show of fireworks will be as useful a study, and as good a discipline for the mind. In what I have been saying, I would not be understood as condemning the methods usually employed in the instruction of older students. Real and scientific instruction it is not difficult to find; but the habits formed in childhood, of which I have been endeavouring to trace the causes, create in the minds of many persons an inability to estimate the advantages of correctness, and a disinclination for the thought and study which are necessary to arrive at it. Still less would I have ventured before you with this criticism, were I not certain that the manner of teaching the physical sciences in this university is in strict accordance with the principles which I have endeavoured to maintain, and is not in the least adapted to feed the appetite of those who hunger for amusement at the expense of such as desire solid instruction. Many may be here present, with knowledge to form a judgment, who have inspected the apparatus provided for the purposes of natural philosophy and chemistry in this institution; they cannot but have remarked, that the whole is, as much as it possibly can be, and in many instances by novel methods, adapted to place before the eyes those numerical laws which were at first considered as mathematical results. It is not considered sufficient that the mathematical student should deduce these conclusions by reasoning from the first principles; in addition to this, the experimental verifications are such, as by themselves would amount to demonstration. This marks the character of the instruction here given; and to enable the student to appreciate and find delight in such apparently dry minuteness, I have recommended that he should begin early to follow the track into which he must turn, before he can be said to be in the path of knowledge.

What is the reason, it may be asked, that the sciences in general, and particularly the mathematics, which are the foundation of accurate knowledge in all, are delayed till what is comparatively so late a period in life? I say, so late a period, because, while it is considered that at the age of seven years, all children may with advantage commence the study of Greek and Latin, the formal pursuit of mathematics is pushed off to the age of fourteen or fifteen. Is it that the latter study is more difficult than the former? Does it require the intellect of a more advanced age? or may any method be devised by which a pursuit so generally acknowledged to be of the highest utility, may occupy its fair place in the system of education? I shall endeavour to answer these questions at as much length as our time will admit.

The difficulties of mathematics are much exaggerated; I mean the necessary difficulties, for I do not deny that to the student of fourteen years of age, whose mind is utterly unprepared for the study, they offer obstacles of as serious a nature as any elementary branch of knowledge whatever. This necessary preparation is seldom made, for which the following explanation may account.

The groundwork of the mathematics is the science of arithmetic. It is the necessary forerunner of algebra, of which indeed it is, or ought to be, a constituent part. It is therefore evident that the clearness of the student's perceptions of the first doctrines of algebra must be most materially influenced by the manner in which he has learnt the principles of arithmetic. Now it is a well known fact, that these principles are not, in nine cases out of ten, a part of the preparatory education of those who commence algebra. It is not that abundance of time is not bestowed upon the subject in our schools, since in most cases, what goes by the name of arithmetic, forms a part of the studies of many years. The defect, which is so notorious, that it is hardly requisite to allude to it in distinct terms, is that the attention is entirely directed to such practical rules as are of most frequent occurrence in commercial operations, and to the *rules* only, not to the *principles* on which they are established. Reasoning and reflection are entirely excluded from a science, which of all is the most adapted for the development of these faculties in the young mind. I am not underrating the importance of readiness in calculation, a habit so essential to the every day pursuits of life. But surely it would be no bar to the attainment of this habit, to mix up with the methods which are to form it, actual demonstrations of the rules by which the student is to be guided. There is nothing whatever in the fundamental operations of arithmetic, of which the demonstration is not simple, practical, and suited to the capacity of the young. I would even go so far as to say, that the science of arithmetic is more easy than the art, and that the labour usually required for the attainment of practical correctness might be very materially lessened by the introduction of theoretical principles. It has been well observed by Condillac, in treating of this very subject, that a rule is like the parapet of a bridge; it may keep a careless passenger from tumbling over, but will not help him to walk forward. While I admit the necessity of such rules, it is as the results of the student's own reflection and conviction—not of the orders of a master, or the authority of a book. I should require to apologize for an insult to the understandings of those who hear me, were I to enlarge any further upon the inutility of the present methods. In answer to those, if there be any, who uphold the present system on account of the importance of commercial operations to a great part of the world, and who therefore think that all should be saddled with the whole routine of the counting-house, I will only observe, that a rule is established in other cases which it behoves them to show should not extend to this. General education is intended to develope the faculties, so as to enable the individual to apply the whole strength of mind with which nature has gifted him, to the purposes of life, and, in particular, to the calling for which he is intended. Common sense, therefore, dictates the postponement of professional instruction till a later period, at least in all cases wherein its prosecution interferes with the great objects to which we have alluded. He would be held to be joking who should propose that all should read Celsus at ten years of age, because many are destined for the profession of physic: nevertheless, as singular an anomaly prevails in education, as far as arithmetic is concerned. In the remaining branches, the same defects are discernible though not to the same extent, and from this system springs the dislike with which the mathematics are regarded by the majority of those who commence the study. What taste for the acquisition of languages would have existed, had it been the custom to permit no one to speak until he had attained the age of fourteen? And how can it be expected that a study which requires thought, reasoning, and logical comparison of ideas, should find favour or be regarded with any feeling but disgust, when, by a careful prohibition of the previous exercise of these faculties, the task is rendered one of very great difficulty? And let no one suppose, because he finds no embarrassment in following a train of reasoning, that it would have been an easy task had the habit been left to be formed till nearly the completion of his education. I know it for fact, that there is no trouble which many students will not take to avoid following a demonstration, when their previous habits have not made it comparatively attainable. I have known the propositions of Euclid committed to memory by rote, even to the right arrangement of the numerous combinations of letters, by those who found such an exercise more easy than the usual method of mastering a demonstration. It is customary to explain so extreme a case by saying, that the individual has no turn for mathematics, a phrase much in use, and which I conceive would be rightly interpreted, by saying that he has turned to them too late.

To return to the subject.—If the system of teaching arithmetic as just described were amended, much time would be saved, part of which might be devoted to further prosecution of mathematical studies. The student would find algebra an easy generalization of arithmetic. He would not see any great difficulty in applying to numbers in general, represented by letters for the sake of abbreviation, those principles which had become familiar to him by constant application to particular cases. If, in addition to this, the suggestion made in a former part of this lecture had been acted upon—if he were prepared with some knowledge of the propositions to which he must look forward, the road would be more short and more pleasant. To know what is coming, to be able to anticipate the result, adds sensibly to the pleasure of acquiring knowledge: we may say, indeed, that there is little satisfaction without it.

Geometry, which is a science more pleasing to the majority of learners than algebra, and which is, for the purposes of the many, the more useful of the two, might be taught at an earlier age than is the custom at present. I do not say that the most rigorous form of the science is that which should be first adopted, since there is much in it which could not be appreciated by the youngest students.

Undoubtedly, geometry is made a part of the usual course of education, on account of the strictness of its reasoning, and the absence of all circumstances which have any tendency to introduce doubt or balance of probabilities into its conclusions. Every plan, therefore, which is proposed for teaching geometry is valuable or not, according as it increases the perception of the force of the reasoning, or the contrary. It is not true that demonstration, however unanswerable, brings immediate conviction to the mind of one unused to it. All must come by experience only to an appreciation of its value; they must, in fact, learn to reason. Any one single argument drawn from an elementary proposition, would certainly, when the terms were explained, obtain an immediate assent: it could hardly be otherwise when we consider that few theorems contain individual reasonings more difficult than the following:—Two magnitudes are each of them equal to a third; therefore, they are equal to one another. But a connected chain of such reasonings, in which, perhaps, at every second step, a new though self-evident principle is introduced, increases in difficulty more than in proportion to its length. I feel that the opinion which I am about to hazard will appear new to many; I know not whether I may not say to all, since I am not aware of any authority for it. As far as I am concerned, it is my own conviction, drawn from what I have observed in the course of my duties in this place. Most people would say, that the arguments of geometry which are incontrovertible, were the means of establishing conclusions which, before the admission of the reasonings, were doubtful. I am of opinion that the reverse is the case: that the conclusions themselves, in most instances of the elements of this science, are so natural, so probable, so evident to the senses, as not to derive any additional sanction from reasoning so new and strange as that of geometry must appear to the beginner. On the contrary, I hold that confidence in the complicated reasonings is taught by observing that they do, at last, lead to evident and undoubted results. Those who are unused to rigorous proof have more faith in the simple and well-tried method of ocular demonstration than in the new and apparently cumbrous and superfluous machinery of mathematical argument; just as the sling and stone was preferred to the armour of Saul, because it had not been proved by him who was to use it. I have been told repeatedly by pupils, on ending some of the most elementary propositions, that they knew that before; and I have found the difficulty to consist in convincing them that they were now to know it in a different way, which would, when understood, lead them to things which they did not know beforehand. Those, then, who will agree with me in opinion that, in the first elements, the results lend force to the reasoning, and not the reasonings to the result, will come with me to the conclusion that the preliminary step to be taken, in teaching geometry, is to increase the certainty of the results by those means which nature first points out. I mean that the first course of geometry should be experimental; that the student should be guided by ocular demonstration to a knowledge of the facts, to the connexion of which he is afterwards to apply his reasoning powers. There is no proposition in the elements of Euclid, at least in the part which relates to plane geometry, but what might readily be proved in this manner. An additional advantage would be, the complete establishment of the meaning of the terms, which would thus be practically fixed in the student's mind, before he enters on the new track which it is the ultimate object of geometry to point out.

A youth thus prepared in the elements of mathematics, might commence the study of physics in a manner somewhat stricter than is usually thought advisable. The greatest obstacle in the way of an earlier attainment of the first principles, both of physics and chemistry, is the expense and difficulty of procuring suitable apparatus, both of which are considerably overrated. The costly and minutely exact instruments with which the cabinet of a public lecturer is filled are by no means indispensable for the purposes of preliminary instruction: they are made to be distinctly seen throughout the space of a room such as that in which we now are; have all the additional finish which the best workmen can bestow; and are made to fulfil, as far as such instruments can do, the conditions of perfect exactness. The apparatus required for our purpose might be simple, cheap, and not containing many instruments: the principles which it is intended to illustrate are few in number; and it would be useless to attempt a degree of correctness, which those, for whose benefit the whole is intended, would be unable to appreciate. It would tend greatly to the reduction of the number of experiments if the student were commonly well versed in the results, not to say the reasonings, of geometry. Truths of this description, by what means soever acquired, are a species of actual knowledge which tend to the better comprehension of the phenomena of physics. The same may be said of the first principles of algebra; a very little of which greatly extends the power of deducing some phenomena from others, and of establishing the connexion between them.

But though the student should grow up unacquainted with the mathematics, to years when time and inclination fail him for the pursuit, he should, nevertheless, if it be in his power, turn his attention to the phenomena of nature, as collected and displayed in the sciences of mechanics, in the widest sense of the word, astronomy and chemistry; and this he may do with perfect confidence, that although he will never compare with the mathematician in the extent and profundity of his views, and the facility of applying his principles, he may, nevertheless, be sure of reaping such a harvest as will amply repay him for his trouble, and render him an object of envy to all who have never paid any attention to these subjects. It ought not to diminish the satisfaction which he feels in wandering over the ample fields that lie open before him, that there are others which he cannot tread, except by another path, to the gate of which, want of time or opportunity has prevented his approach; for he should recollect that those who have been more fortunate and have reached a point which to him appears distant, are nowise nearer to the possible limit which bounds the human power of discovery. Facts and principles which Newton or Galileo would have gladly known, are spread before him in abundance: the researches of the mathematician, and the labours of the observer, are now divested of technicalities, and reduced to such a form that he can seize results which, not many years ago, were concealed in the covering of mathematics under which they were born and nourished. A century has not elapsed since an affectation universally prevailed, which was equivalent to a declaratory law, that he who did not know all should know nothing. Although the use of a learned language was, in a great measure, abolished, there still remained a method, as effectual, of concealing the stores of natural science; and this, without any overt act against the progress of knowledge, which the liberal-minded of that day would have scorned as much as if they had lived in the present age. Their error consisted in taking no pains to simplify elementary knowledge; in not endeavouring to clear the entrance of the building which they took so much pride in erecting. The case is altered now:—men of the highest acquirements are not ashamed of the task of placing before the world, in a shape intelligible to all, as many of the truths of natural philosophy as will admit of it. This is the age of elementary works as well as of remarkable discoveries: but among the many advantages which it possesses, and which, in spite of all that has been said of them, have not been too much boasted, there is one rising defect, which all who value real knowledge should exert themselves to counteract.

It is natural to man, when he gains what he feels to be an advantage, by an unusual or unexpected method, to look down upon and decry the means of which others are making use for the attainment of the same; even though the latter should be acknowledged to be, in the long run, more effectual. This, if I mistake not, is beginning to be the case at present: while the simplification and consequent extension of natural philosophy has made many well informed thinkers on this subject, and thousands of superficial readers, a notion begins to be formed as if the mathematics were unnecessary, and as if all requisite knowledge could be gained without them. Unnecessary we have shown them to be in a certain sense, inasmuch as valuable information can be gained without them; but what comparison is there between the mathematician and natural philosopher, and the latter character separated from the former? less than between the scholar who had read his authors in their native language, and the man who has contented himself with a translation. Even allowing the results to be the same in both cases, which I am far from granting, supposing that both of the first class understand equally well the phenomena of the motion of a planet, and both of the second the events of the Trojan or Peloponnesian war—it is the manner of arriving at these facts which will plainly mark the distinction between the two the moment they are brought together: the one has improved his mind and extended his faculties, by following the track of discovery; should he even forget what he knows, he has not lost all—he cannot, if he would, rid himself of the habits he has acquired: the other has heard the recital of the voyage—has added to his stock of information, but not to the powers of his understanding; he receives what he is told, but cannot certainly know whether it is right or wrong.

In estimating the advantages of such attention to real science, we must not forget that time will be thereby saved in two ways; the path itself will be more easy to travel, and the period at which it is entered upon will be earlier. Thus the elements of many other sciences may be added to the usual course of education, which at present are excluded from it by considerations of the want of time for their cultivation. The study of the structure of our globe, so prominent an object of curiosity at the present day, so useful in the study of geography, as it should be, might, to a small extent at least, form a part of elementary education. The elements of mineralogy, as far at least as they are necessary to the study of geology, of which the first is the grammar, would offer no difficulty to any one acquainted with the first principles of chemistry. Natural history, a study so pleasing to the young, and so conversant with familiar objects, that it has often been proposed as one of the first objects of attention for children, would enlarge the mind by calling the attention to the countless examples which there exist of the adaptation of means to their end. No one of these sciences is destitute of instances of strict reasoning and sound practical theories. Neither the time nor my own knowledge of these subjects will permit of my entering into the manner in which they should be taught. One thing is certain: that as there is no one science which does not aid in the advancement of all the rest, so there is no useful habit of mind acquired from the study of any one, which is not beneficially felt in proceeding to the others. The cautious habit of observation acquired from a correct study of physics and chemistry, finds ample exercise in those of geology or natural history. The correct, close, and sustained reasoning of mathematics is useful throughout. Nor is this connexion observable only between those parts of knowledge which go by the name of sciences. The study of languages, so necessary to them all, receives from them, in its turn, illustration and ornament. History, metaphysics, political economy, frequently require some collateral knowledge, which is to be derived from the phenomena of nature. But it is needless to further pursue truths which will find an almost universal assent.

Thus much have I said upon the study of science, as a part of the education of all, and as tending to promote the great object, the development of the faculties of the mind. All that I have hitherto observed is grounded upon considerations quite independent of the practical utility of the sciences, and would lose none of its force were they mere speculations, in nowise affecting the progress of the arts or the increase of the conveniences of life. I now come to other considerations. We are all aware that mathematics and physics, so useful to all, from the training they afford, are to many a part of their professional education, bearing closely upon matters of the highest concern to a commercial and manufacturing nation. I therefore request your attention to some observations which are of importance at any time, but which have struck me particularly as deserving, in a remarkable degree, the attention of those who live in an era such as our own.

A wide line of distinction has been drawn between two branches of knowledge which have been called by the names of theory and practice. No appellations have been more misused, as indeed we may suspect when we recur to the fact that they have become the watchwords of parties in science. According to some, a theorist is a person who indulges in general and speculative views, without giving his attention to useful objects, and such as are of immediate concern to public interests; while a practical man is one whose knowledge directly relates to those parts of science which can be immediately turned to account in navigation, machinery, and commerce, or some other direct application. According to others, a theorist is one who has really studied the matters in question well and scientifically; while a practical man is like the common soldier, whose employment it is to carry into effect that which others have projected. Much discussion has ensued upon these names, into which it is not my purpose to enter. The fact is, that theory, in the proper sense of the word, is that without which practice cannot thrive, and the two must be united, in whatever way that effect may be produced, before any real good can result. The first order of talent is divided among men in various ways. In some, it turns towards those branches which can be pursued in the retirement of the closet;—in others it engages the mind in the pursuits of busy life, and the applications of the phenomena discovered by the first class; while to the reputation of both it would be of the worst consequence could their disputes upon words effect an actual separation between them.

This country has long held the first rank in the useful arts, which depend upon the applications of science. This is not a boast, since it is a fact candidly admitted by foreigners, and demonstrable to the senses of all whom travel and observation have enabled to verify it. Nevertheless, it is as true that there are other countries where theoretical knowledge is more generally diffused. This has given occasion, I doubt not to many, to depreciate the latter species of knowledge as a professional disqualification, on the ground that our country, in which it is less cultivated, has nevertheless kept its station, and even gained upon others in useful applications and practical arts. But these, I think, do not consider that, independently of our being able to draw from the stores of others, our relative political situations have been different. To make this apparent, we must consider what has been the reception of science in this country and others. For political opinions, this is not the place; but admitted facts, when they bear upon the subject now in question, are open to my use; and I shall avail myself of them, to show in what situation we may probably stand, if we neglect the diffusion of theoretical knowledge.

When the sciences were first revived in Europe, the despotic governments of that time, well aware what enemy had made his appearance, and knowing that their system of policy was based upon the universal ignorance of the times, used all their efforts to crush its supporters and to prevent its diffusion. This very ignorance supported them in their undertaking, by attributing to sorcery all results of knowledge which were beyond the comprehension of the vulgar. Gradually, however, this state of things ceased to exist, and science, which had survived all attempts at its destruction, became an object of respect; but still its course, in Britain and abroad, was differently modified by the character of the people and their governments.

On the continent, the higher powers began to conceive that what could not be conquered as an enemy might be useful as an ally, and they took into their pay, if I may so express it, the sciences and their followers. Discoveries were rewarded, and those who made them were connected in some manner with the government they lived under. To it they were made to owe their means of subsistence, and thus placed beyond the cares of life, they were enabled to turn their attention to that which they most esteemed, to the advancement of the sciences and the perfection of the theory, without having to consider whether that on which they were occupied could be turned to immediate account or not. Practical application was in high repute as far as it could be advantageous to the ruling powers. The government was the only customer which was well served: its armies, its public works, displayed all that skill united with labour could effect. The people, on the other hand, deprived of useful knowledge, and of all stimulus to improvement and exertion, sunk into a listless dependence on the arm of the state for the supply of all public wants. To this day such is the case over a great part of the continent, even among acute and enterprising nations. The practical arts could not be expected to flourish in such a state of things, and accordingly they have been stationary, or advanced with tardy steps when compared with the rapid march which they have made in England.

In this country the more popular nature of the government has given another species of impulse to scientific knowledge. The commercial character of its people, and its division into little parishes, each attending to its own concerns, and paying its own expenses, has, with other circumstances, thrown upon every individual the necessity of attention to all matters which immediately concern him, as well of a more public as of a domestic nature. Thus each one, secure of no interruption from the jealousy of government, in endeavouring to convert any improvement in art to his own benefit, has been left to employ all his talents in any line to which his interest might induce him to turn. The consequence is, the high state of practical perfection in which we see the useful arts; the readiness with which every hint, that holds out a fair prospect, is caught at and adopted; and the facility with which capital to any amount is collected for any public application of science of which the want is felt. But in the meanwhile little encouragement is held out for the pursuit of abstract knowledge. All will naturally direct their attention to that which offers the most immediate prospect of advantage. As a profession, therefore, the pursuit of theoretical science has sunk in importance; and though we are not, nor ever have been, without our share of those whose labours have been successful in this department, yet the number of them has borne no proportion to what might naturally have been expected in a nation whose very existence may be said to depend upon the arts, of which theoretical science is the parent. Nor will the introduction of the illustrious names which our history presents advance an opposite argument; for in appreciating the state of theoretical knowledge of any particular country, I do not look at a Newton, a Lagrange, or an Euler, of whom one country produces but few, and at distant epochs; but at the knowledge of the many, who are to direct the exertions of their fellow-countrymen;—to the ranks from out of which such men must spring.

These are in my opinion the causes of the advancement of theory abroad, and its stationary character at home. But now this combination of circumstances in our favour appears about to cease. We shall have rivals on the continent of Europe, of a character different from those who have hitherto appeared. To all the advantages of a wide diffusion of theoretical knowledge, prepared for them in the days of dependence on their governments, they will add the energies of a people unfettered by the restrictions of what was supposed to be state policy, and awakened to the desire of being themselves the conductors of their own affairs. There are many among them who are well aware of the causes of our superiority, and whose knowledge of the manner in which to overtake us is equalled by their desire to show the path to their fellow countrymen. What then should be done to communicate among ourselves an impulse similar to that which they are now receiving? Nothing but to follow their example, to put in operation the means of remedying the defects of our scientific system. Our task is the more easy of the two, since knowledge is more readily acquired than habits; but performed it must be, if we would wish to maintain our superiority in commerce and manufactures. And this may be done with the additional advantage of rendering elementary education more consonant to the admitted maxim, that the facts which are taught are principally valuable on account of the habits which are formed in the acquirement. We have then to begin a contest of intellect, one which will increase mutual respect and good-will, as much as that of arms promotes national jealousy and animosity; we must seek the only power which cannot be taken from us, that which is derived from superior information, in the only war from which both parties retire winners, that of rivalry in the diffusion of knowledge.

THE END.