William Reed

On the utility of physical science as a branch of school-instruction : Inaugural-dissertation for the attainment of the degrees of Doctor of Philosophy and Master of Arts at the University of Rostock

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University of Rostock

by

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It is but echoing the voice of all around us to say that society is in a transitional state: so confessedly is education by which a man is prepared to take his position in that society. By degrees we are drifting away from our old moorings; popular belief has been shaken in the infallibility of the classics as the sole instrument of education; philosophers are pronouncing against the cumbrous method by which they are taught, and above all from the overstocking of professiony, and the consequent struggle among English youth for an honourable maintenance, there is a desire to shorten the curriculum of education; parents are disgusted at the lenght of time which it takes for a boy to acquire real proficiency in Latin and Greek, and at the apparent poverty of the ultimate result; we are looking in various directions for some quicker mode of instruction which may at once stimulate and brace up the intellectual capacities, and at the same time afford a useful basis of information, whereon professional knowledge may be raised; in a word for some branch of study, the result of which may be an end, and not solely a means.

Where one system is giving way to another, the first efforts in the new direction are ever spasmodic and tentative: there must be a reign of confusion before order is restored: — So has it been in our religious and political revolutions; so is it now in the educational movement

We have found out the mistakes of the old way. For instance that monstrous fallacy of insisting on volumes of technical grammar being learnt by heart; without letting one ray of light into the darkness before the unfortunate boy by explaining the end to which the apparently unmeaning gibberish is to lead him; a system which might be parallelled by teaching Italian through the committing to memory of the „Divine Comedy", thought this latter exercise would be play compared with the former, for the poets musical rhythm would have charms for the ears of some who are repelled by the harsh doggerel of the „propria quae maribus". Or again the putting together by the apt and inapt alike of Latin verses after the manner of Chinese puzzles the pieces for which in a more or less complete arrangement were to be hunted for in the „Gradus", and then twisted about till they resembled in some remote degree the given pattern of Ovid or Virgil. — I do not disparage the study or imitation of those most exquisite models of taste, the great classic poets, in the case of those who have time and talent for such elegant pursuits; but what I as protest against is the exaction, by compulsion, of verses (poetry I can not call them) from all boys in discriminately up to 18 or 19 years of age; in fact ignoring the good old saying „Poëta nascitur, non fit".

These errors then, I say, we have discovered; but we have not yet remedied them. The substitutes proposed are many and the advocates of the new methods of education do not agree among themselves: — this alone is certain that the old system as hitherto pursued is doomed. — Some of the public schools to avoid the shock of a sudden revolution are by degrees introducing new subjects as supplementary to the old among others both mental and

physical science. It is well that the change should be made gradually; time is thus given for free discussion on the respective merits of various branches of study, and for maturing and organising the new system. Mr. Mill, and others, have thrown out useful hints from a general view of the question. What is now required is that some of the subjects recommended as instruments of education should be put into a practical form for this purpose. Before however I come to the main point of this essay, viz. the claims of physical sciences as an instrument of education, and the method of their study, I must say something about education itself generally, and what I believe to be its ends and objects. It would be useless and manifestly absurd to estimate and compare the means of education, if we had not made up our minds as to what education is, and what we are to set before us as the attainments desirable to be acquired by it. Education, of course, in its most extended sense includes the whole process of human instruction physical, intellectual and moral: — but here I limit it to the preparation of the mind of youth for its function in the world generally, and in its own avocation specially. Thus its province is twofold; 1st. The absolute training of the mind without reference to the special calling in which it may be destined to engage, — its lessons in taste and accuracy, its habituation to sustained thought, the gradual imparting of the power to weigh facts fairly on both sides of a question, and thence to judge soundly between them. This for distinction's sake we will call „general education". — 2nd. The acquisition of certain knowledge, or a certain body of facts and principles suited to our special calling, and which may be specially useful to each of us individually according to the course of life

we choose. This we will call „professional education". — It is important that these two branches of education should not be confused, for each has its own particular function which can not be dispensed with. Neither must the boundaries of either be unduly extended at the expense of the other. The importance of the former has, as we have seen, been exaggerated by compelling all alike to submit too long to a system from which many ceased to profit: — the influence of the latter, from reaction, is not unlikely in its turn to be over-exalted. Let us see why this is dangerous from a rapid survey of the effects of both: and we shall at once perceive how each is supplementary to the other, and how the omission of either would leave a vacuum in our intellect. There is a large sphere of the training of the mind which must necessarily be the same in the case of all men, or at least of all those who are born approximately in the same grade of society: — viz. that which includes all those requisite acquirements which I have mentioned as the result of general education: — we all require taste and precision of thought, — that is the talent of saying and thinking the right thing at the right time, — and having a clear, accurate, and what is technically called „logical" method of thought. We all alike whether clergy, or doctors, or men of business, require the power to concentrate our attention in a sustained manner upon the subject before us, and not to dart from one thing to another in a volatile and childish manner. Above all, in every walk of life, we need to be accustomed to give a fair hearing to all arguments, pro and con, in any many sided question, and each for ourselves to form sound judgements upon evidence. In all these particulary the education of all men should be the same. Of course, those born in the humble grades of so-

ciety, and who must be early instructed to earn their bread by their handiwork can only be imbued with the barest elements of general education: on the other hand those in the very highest stations who make men and politics their study require little professional training! But I am speaking for those between these two extremes, who in addition to this general, need some special, and professional training: — and for you, one and all alike, I assert that this general education, as a preliminary, is absolutely necessary. For, let us see what would be the result if each of us were from the earliest years simply instructed in technical and professional lore.

Putting aside the difficulty of ascertaining, at eight years old, the avocation for which each is by nature specially suited, and the probability of his changing his mind at a maturer age, we will suppose that the future profession of each of us can be divined, and that from our earliest in fancy we are trained with special reference to it. Thus the boy intended to be a doctor would be continually instructed by medical illustrations; the future clergyman by ecclesiastical historics and doctrinal controversies; the destined merchant by mercantile and monetary detail. What would the result be? — The first and probably the most notable consequence would be this, — most men would hate the very name of the profession for which they were destined. But even putting aside this difficulty, and supposing that each could be taught to concentrate all his thought and energy upon it, he would then probably do so with tenfold energy, it may be, violence, and in every avocation we should have selfish, bigoted, and narrow-minded men, taken up with their own concerns, and unable to give a glance toward their neighbours, incapable of sympathy with, and utterly indifferent to the prosperity

of any class but their own, callous to the influences of nationality and patriotism.

History tells us that there has been no power more instrumental in dwarfing national intellects and impeding national developement than that of caste; and if any parent in his desire for an early start in life, and early remuneration for his son, wishes to curtail or dispense with „general education" altogether, I would recommend these considerations, and these facts to his notice. —

We have seen what I believe to be the primary requisites in any instrument of education, and the qualities of mind which it should tend to engender. In the second place we must glance most cursorily at professional education. Any observations on such a subject must of course be most general: for to treat exhaustively upon it would require almost universal knowledge, so various are the employments to which we may be called. To begin with we may observe thus: (I.) That if „general education" has been properly pursued the mind will be in a state apt to acquire quickly and to store systematically any body of special facts or principles which may be committed to it. For instance if you have been generally instructed in the principles of mathematics, and enter a house of business you will of course at once have a power of comprehending its financial transactions which it would have taken you long to acquire by simple practice. If you become a lawyer, or a politician, the habit acquired of thinking and speaking clearly, and of judging soundly will at once enable you to take in arguments from different points of view, of a question which would otherwise have appeared a chaotic puzzle. (II.) From this observation one other follows, viz. that we must try to connect professional and general education as closely as possible.

When we give up the general studies pursued at school, and begin to prepare for some profession we must not look on the knowledge already acquired as a thing of the past, to be at once forgotten or discarded as useless, or at variance with our special studies. This is a very common mistake attributable partly to mere thoughtlessness and to a childish feeling of delight at supposed freedom from earlier restraints, partly to the dull and unattractive way in which knowledge is too often imparted. On the contrary we must regard the one as growing out of the other, — or rather technical education as being simply a minuter study of some particular branch of which general education from its very universality could only give a bare outline. For instance a general education ought to have given us a rough sketch of the history of England, and an idea of a few of its leading principles, and indeed of the different phases of political progress in the history of the world. If then we have to make ecclesiastical or constitutional history our special study, we should hardly discard all our previous knowledge as if it had us bearing on the question: however fragmentary, it will be of great use to us as supplying certain landmarks in our country's career, around which we may group our collection of particular facts and incidents, — certain principles under the heads of which we may range phenomena now for the first time observed. Or again a general education should give us an insight into the general physical laws of the world around us, so that we may for the future be able to assign intelligible causes to effects which would otherwise have appeared strange and alarming, even though our knowledge may not enable us fully to interpret them. In the same manner, whatever our special work be, we should utilise to the

utmost of our power all early acquired information. As a corollary to this it suggests itself, that for those who are to be engaged in practical occupation, — and who in some way or another are not?, — this general education should as far as possible be in subjects whose bearing is practical so that there may be as little break as possible between the earlier and the later training.

Thus we have seen what should be the great ends of education, and what qualities of mind we should seek to promote by it beyond this we have concluded that it must be employed in two ways, generally and specially, with the former of these provinces we are of course chiefly concerned. We must now proceed to the direct object under discussion, — the consideration how far are the physical sciences calculated to effect these ends, and promote these intellectual habits? — and as a secondary consideration how are they to be taught, and learnt, with this purpose in view? Firstly as to the general habituation of the mind to think: — Classical, artistic, and liuguistic accomplishment depends much upon natural aptitude: progress is so to speak by fits and starts: one mind has power of estimating subtleties which another has not, and of reproducing them unconsciously, as one is more apt at certain exercises, riding, skating, or others, than another: — to use common language they come naturally to some. Now this very natural aptitude becomes a snare to them and possibly to others: the boy who finds he has an almost intuitive perception of the refinements of art or language, generally bekomes careless from his very ability, — intense application is not required: the most brilliant touches of fancy in composition seem to come spontaneously; often to succeed inaction: hence there is much in his temperament to dis-

courage sustained thought. On the other hand the boy who is conscious of dullness or inaptitude in apprehending these studies is often deterred from persevering effort by comparing his own inability with the apparently unequal gifts of nature to his cleverer rival. I am not going to advance such an absurd proposition as that all minds are equally capable of proficiency in science: — but this, I think will readily be conceded that in scientific study we all start much more on a par than in those other studies to which I have alluded. Of course some of us have been already more carefully observant of nature, and of all that goes on around us, and so start with a larger body of known scientific facts, — some of us are more inquiring than others, and have from earliest years been used to acquire all the useful and practical information possible from those capable of giving it. But giving full weight to these natural differences of character, there remains a clear balance in favour of scientific over artistic or classical studies, as a fair contest in which mind can compete against mind. The information already acquired on scientific facts, when we seriously begin education, is generally of so desultory a character, that we can not see its place in a systematic scheme, or often so one sided and erroneous as to be little short of useless. The first great point then to be observed as of educational value in the study of sciences is the seriousness and system of purpose which it claims from every mind that enters upon it. I do not say that a man can become proficient in any study to which he does not seriously give his mind, but science above all others requires his undivided attention, and at the same time, when this is given, is comprehensible to almost all of us. Fact is here so clearly ranged by the side of fact, and many

facts are brought under one principle, and lower principles under higher, in other words the study is so evenly progressive, that our incessant application to each step is required, or there is left a gap in the mental structure and we have but a confused instead of a plainly traced idea of the whole.

Now the most penetrating of ancient philosophers has told us, and indeed our daily experience tells us, that successive acts produce habits of mind — we are not born with this or that disposition from which our acts follow, but the constant doing of acts, in time produce habits. Hence the great value of this study of science which imperatively demands acts of constant and systematic attention, and so by degrees engenders in our minds an unconscious habit of giving our whole thought to our every occupation for the time being, a habit which we all find eminently conducive to success, — a saver of our time as preventing all volatile and unprofitable thoughtlessness, and a contributor to our happiness, which has been well defined as consisting in virtuous and intelligent energy. The next advantage which I would touch upon as accruing from a scientific education is the power of judging rightly on evidence before us. We are all required almost every moment of our lives to make conscious or unconscious judgements between conflicting evidence, and yet how much are we the creatures of prejudice and prepossession, and consequently how often unfit to perform this duty!

Now science by requiring especial care in this process is preëminently conducive to the developement of the judging faculty: the very derivation of the word shows us that it is concerned with that which is known, and not with that which is believed, or opined, or guessed at. As we shall see hereafter a care is required in the investiga-

tion of phenomena scientifically, of which we have no conception in common life: and where this care is more required, and its results more capable of verification, from those sciences do I think the greatest intellectual benefits result. In art there are of course some vague and large principles which can not within certain limits be transgressed but art is, as it was said of old, closely linked with chance „τέχνη τύχην ἔπερξε καὶ τύχη τέχνην".

In the composition or translation of language there is no absolute right or wrong, (beyond grammatical propriety,) there are often many ways in which the same thought may be expressed with equal elegance philosophy jumps at great conclusions and there may be much truth in conflicting systems. But science requires a demonstrable certainly, and hence banishes all vagueness from the mind, and gives it the clearness to judge fairly once for all.

These then are some of the advantages of scientific education: but it will at once occur to you that the sciences, i. e. the branches of knowledge concerning which we possess a body of facts, are many, and that it is past human power to have an accurate knowledge of each of them even after a life-time of study, much more so in the short period you are able to devote to your education. I will proceed to draw a distinction between different classes of the sciences, and point out those which in your circumstances and at your time of life you will find the most profitable instrument of education. Before however proceeding to do so, I must clear up what may possibly be a difficulty in terminology, — I mean the terms „object" and „subject", — and their derivations „objective" and „subjective". It is most dangerous to use these, or any similar philosophical terms without knowing the exact

meaning we give to them. The „object“ then is anything and everything external to our own thinking mind. The „subject“ is that thinking mind. And consequently „objective“ and „subjective“ are applied to all respectively which are without or within that mind. As for instance it is often questioned whether size, and weight, are objective existences, or only subjective effects; that is to say whether they actually exist independently of us, or are only sensations produced in our minds.

We will then divide sciences into those of the „object“ and those of the „subject“, — or roughly into the physical and mental sciences. The former including Chemistry, — or the science of inorganic matter, — Physiology, Botany, etc. The latter Morality, or the science of the moral element in man, Psychology, or the science of the mind itself and of its mode of action etc. — Now, for several reasons the physical sciences are much more fitted as a means of youthful education than the moral. Firstly, because the youthful mind is not naturally subjective; i. e. it does not willingly study itself, but the things around it. I would not for a moment advocate the pernicious doctrine that that alone is worth learning which for the time amuses us — nothing could be more destinctive of serious and useful knowledge, for there are hardly any of us who like elementary instruction, and so if we consulted our temporary pleasure we might remain ignorant and useless member of society all our lifes long: — but when after long observation and careful study it is seen that there is one class of sciences towards which the youthful mind is instinctively drawn, and another from which it is repelled we may unhesitatingly conclude that the former is more

likely than the latter to be a good means of intelligent education.

Observation and the consciousness of each one of us must tell us that till the age of, say, 21, or so, the mind is not subjective: an intelligent boy will be ever accumulating facts about things around him, but the will not sit down to think about his own mind, why the human mind has different and conflicting passions, and how its impressions are associated into groups. This opinion is strengthened by serveral facts which we must have observed. The men who have written in early youth, poets and prose writers alike, all treat of what is around them rather than of human nature: and this is especially observable because those whose writings at this early age are preserved to us are of course people of the highest genius, whom we might expect to be more precocious than ourselves, and consequently to become „subjective" earlier. Again, as boys, we all rejoice rather in those authors, whose subjects are active scenes of life, than in those which we should call sentimental. We thrill with delight over „The Armada" or „Ivry" of Macaulay, long before we can appreciate wordsworth: — and rejoice in the narrative of Walter Scott's novels long before we can see any truth or fascination in his introductory letters in which more matured thought can trace exquisitely philosophical delineations of character. These and other examples which will easily occur to us indicate that a boy's mind is not „subjective", — and hence one reason why the physical sciences are a better means of education than the mental.

Secondly, again, the facts with which they supply us are more generally useful. I do not mean to depreciate the knowledge imparted to us by mental and moral philo-

sophy, to know how the conscience from a bare capacity for receiving moral impressions is gradually developed by training and exercise into the most refined judge of moral action, or to recognise the law of the association of ideas and its consequent influence on habits, is more than an interesting study, it may be pregnant with good to those who are destined to mould and guide the thought of others: but the mass of mankind have not leisure to master, and scarcely ability to appreciate these truths. — On the other hand every class of men must necessarily be employed on physical matters; must constantly be called upon to form judgments concerning them; which for the most part they base upon the hasty inductions of empyricism, — where a very slight acquaintance with physical science would often deter them from absurdly erroneous conclusions, and point out a safe course amid a sea of conflicting difficulties. Every man finds it of practical use to know the physical or atmospheric condition under which human life is in danger of extinction, to know what means may effectually be employed to counteract those influences, to have some notion of the chemical properties of minerals or vegetables which may be presented to his notice, to foretell the social and intellectual effect which certain climates, or natural aspects of a country, will have upon a nation, and the types of character they will produce in mankind. For all these and similar facts have been and may be grasped by the patient and intelligent student of physical science.

There is another way in which we may see the superiority of the physical sciences — especially as a means of education. I refer to the capability of testing their results by experiment and observation. There is nothing more satisfactory to the young mind, or indeed to all minds

than to see a clear proof of a statement or theory. We may see the conclusions of the astute moralist or psychologist actually verified in life: but most of their theories have much to be said against them, and those least disputed require long time and study to verify them. But the conclusions of the physical philosopher are for the most part capable of immediate proof, and that so to speak in your hands, and before your eyes. To give you a very plain instance of the comparative interest attaching to the conclusions of a mental or a physical inquirer. One of the greatest questions in mental science has been, „What is the origin of conscience?“ The one school has ever held that each of us is born with a faculty ready developed for distinguishing between right and wrong; — the other that our mind comes into existence as a „tabula rasa“, i. e. a bare, unmarked tablet whose every impression is made by training and experience, and which might be as well trained to regard what we consider wrong, to be right, and vice versa. You will all allow that this is not a very interesting inquiry to your minds, or one very capable of verification on either side, or of great practical utility to the world at large. The philosopher of the former school will appeal, as proof of his theory, to the fact that there is in all men, however various their developement, a certain uniformity in their sense of right and wrong. The advocate of the latter will give as evidence on his side examples of the diversity of what is called man's moral sentiment. How do you account, he will say, for the difference, patent to all, between the dictates of a Jewish and a Christian, of a Catholic and a Protestant conscience? Each party has some reason on their side, yet neither has convincing proof. Till the secret state of a new born mind

can be laid open to mortal gaze, the question must remain insoluble. — Compare with this a physical question. The position of the diamond in the mineral world was long debated. By an hypothesis from certain analyses a few years ago, it was conjectured that the diamond was combustible, — a conclusion surely more startling to our prepossessions than any of those of the mental philosopher. Yet how different is the evidence of this hypothesis! The crucible is brought, the diamond subjected to a high degree of heat, and that which we have been used to associate with a high degree of intensest durability is consumed.

This is but one instance among many, — but it shows you the superiority of physical over mental science, as a study for education's sake. — That study, whose results are patent, intelligible, and so interesting to all, must stimulate thought and inquiry, and so aid in the mind's enlightenment. —

When I first began to consider the requirements of a modern education, I alluded to the fact that we now expect from it something more than a means to an end: in other words that in the mind which has passed through its curriculum of training we look not only for a bare capability of application and judgment, but also for some ready store of useful and practical information: — and as a corollary to this I decided that the subjects of general education should if possible have some bearing on the special and professional training of each one of us. Now considering the great variety of vocations to which we may devote ourselves, it is hardly fair to expect that some physical science should have special bearing on each of them. Yet how few employments or relaxations of life are there in which some knowledge of physical science is not useful

and pleasurable! Here again they may favourably be contrasted with the mental sciences. The man who can give a clear account of his theory of the conscience, or the will, can not be compared, as a useful member of society, with him who can render aid in case of dangerous disease, or poisoning — and this very practical nature of physical science reacts upon its purely educational value, for he who finds direct benefit from his knowledge will surely be stimulated to prosecute his studies farther. Such then are the important ends which I believe to be attainable by a study of the sciences, and especially of those called physical. To recapitulate them they are principally these: The habituation of the mind to sustained thought and reasoning, — and to the building up in a connected way of truth upon truth as one is deducible from the other: and also the acquisition of a power of judgment, — and as a preliminary to this of some knowledge of the great difficulty which there is in judging evidence before us.

We come now to the method in which physical science can be best imparted. We must be content in an essay of this lenght, to treat of this subject cursorily, and must not attempt an exhaustive consideration of it. In many details each science must have a method of its own, according to the amount of data now possessed by it, or to the power of observation or experiment which it presents to us. Physiology from the complexity of all its phenomena can not be illustrated by the crucial experimental tests of which chemistry admits. We must therefore be content to observe many facts concerning it, and so gradually and carefully arrive at general truths concerning it.

But in chemistry the studies of great minds and the experience of those who have gone before us, has already

provided us with a large body of principles and demonstrable truths, and so our province is not so much to work upwards in the discovery of general laws and principles, but rather to illustrate by experiment those which have been established by great chemists, and to convince ourselves in this manner of their probability and to possess ourselves of the means of demonstrating it to others.

The method of science however, i. e. the mental arrangement of all known scientific facts and laws is almost beyond the province of general elementary education. — What however is of the highest importance, and nearly concerns all scientific knowledge is not only the method of scientific facts, but also the mental disposition in which we look at them, whether that disposition be acquired by self habituation to it, or by the manner in which the subject is taught to us. — Now there seems to me two opposite tendencies to be especially avoided as grave faults in a teacher, or in a learner. The one is the imparting or the receiving instruction in a dull perfunctory manner, as if it were something to be done and got over, necessary perhaps as a troublesome exercise, but devoid of ultimate results, or real practical utility. This method speaks for itself as being utterly futile and unprofitable. No instructor can instil interest or enthusiasm into others if he possesses it not himself and no pupil can progress in anything towards which he will not stir up his energies, and on which he will not rivet his attention: but more, the evil does not cease here: The act of listless in attention to what is going on involves greater consequent evils than even waste of time: — it engenders in us an evil habit of carelessness and passivity: we begin by being listless because we do not care to know, or to understand, — we end by being

unable to give our attention to that, the apprehension of which we dearly long-for, from the fact of our minds being totally unaccustomed to application. — This perfunctory mode of teaching, or of submitting to instruction must be at once avoided. It often originates in a dull method of technical expression, devoid of all practical illustration: the youthful mind is not adopted to make intelligent use of long abstract statements, or lists of elements, or general and species, without being in some degree informed of the eventual application of this knowledge, or seeing some concrete illustration of that which is prima facie unintelligible. This is one danger to be avoided. The other is an excess in the opposite direction, viz. playing at learning. We all know how much more attractive things appear at a distance than we find them really to be on close inspection. Thus we often hear those who have, or fancy they have peculiar inaptitude for classical learning talking of the beauties and interest of physical science, in glowing terms; and comparing their present state of ignorance with their probable state of advanced knowledge if the mind were only educated through the medium of physical sciences. When however we analyse these fine conceptions of would-be knowledge and study, of what do we find them to consist? The science of astronomy it is believed is to be learnt by looking at comets and eclipses through telescopes on summer evenings: and that of chemistry consists in the making of pink and blue fluids out of two colourless ones! The poor enthusiast, who looking at some far off view of knowledge, standing out in the beautiful unreality of distance, deems it easy of attainment, may be sure he is mistaken. There are no royal roads to learning. Some of us have aptitude for one of its branches, and some for another: and it is

well to take advantage of these predispositions, but in nothing can real practical knowledge be acquired without toil and application.

So much, of our mental disposition in teaching and learning. We require however something more than ability and industry. We require „method". Method has made easy to man the greatest works. Works which his unsystematised power and labour would never have accomplished. In the material world the discovery of the lever enabled him to use his bodily strenght in a way never before conceived possible. In the intellectual world the inductive method systematised by Lord Bacon, has enabled us to enter upon these very sciences which we are discussing, not as hazy speculations, but clearly comprehensible bodies of facts. Method then we will now consider. Our first idea of method is simply the course we pursue in our own studies. But I use method here in a more extended and technical sense: viz., the plan according to which scientific knowledge has to be arranged by ourselves and others: — we can scarcely hope to discover new laws and facts in science, we must be content to master some of those which have been drawn up by others.

Scientific methods then are two, — corresponding with the two modes of the mind's action: viz., from facts up to laws, or downwards from laws to facts. These methods are called „induction" and „deduction". At the risk of giving very trite illustrations, I must here as simply as possible, by means of practical instances, point out the difference in the working of these methods, and their respective merits and demerits. In the inductive method we begin by observing single instances comparing and classifying them and thence inferring general laws. For

instance, we observe that fire burns paper, that it burns wood, that it burns flesh: — we remark this uniformity or law in its effects, and establish it in a general proposition „fire burns". This is induction. Or again we see that a stone when thrown into the air falls to the ground, that a piece of lead does the same, that a feather, (unless artificially or otherwise buoyed up by the wind), does the same. Here is another instance of uniformity, viz., „there is a tendency in all bodies, when unsupported in the atmosphere, to descend", which we call „The law of Gravitation". Here is „induction" again. —

Let us now look at the converse philosophical method. Suppose we have an established law that „fire burns", and in consequence of this general known fact infer that it will burn any particular thing, — our hand, or a £ 5 note: Here we apply a general law to a particular fact: this is deduction. Or again, the law of gravitation being granted, if we infer that to leap off a roof will result in a fall, we apply the general to the particular instance: — we use the deductive method. You will see at once that the inductive method is best adapted for those who are groping after knowledge in uninvestigated fields: the deductive for those who are but applying the stores of knowledge they have already gained, or which has been acquired and systematised by others: — that deduction is the method of a perfect, induction of an imperfect science. —

We do not however now expect to start any new theories, or discover new laws: we want simply to acquire soundly the outlines and elements of some of the physical sciences. In estimating the respective merits of these two methods, we will look chiefly to the ease with which they present a clear outline of science to the hearer.

On the side of induction it may be said, — that we see each ascending step clearly for ourselves, because we only infer laws concerning that which we know and see, consequently that there is little risk of confusion in bare generalities, and useless superficiality. Historically considered the inductive method has been that throught which all progress in physical science has been made, and consequently there would seem some special fittingness between this means and our end. — On the other hand it may be said that we are prone to make premature and foolish inductions, (though this argument applies rather against the method as a means of investigation, than as of one of education), and that their absurdity soon being apparent we are left in doubt and distrust.

Again, that it is a cumbrous method, and involves many slow steps over which we might easily skip. And, lastly, and this seems the most valid objection in part, that it is dull, and uninteresting, causing us to remain long over minute and bare facts, without giving us a general and clearly-mapped survey of the science which we are going to investigate. — After endeavouring fairly to strike the balance between these converse systems, which you will perceive are but different ways of looking at some one body of scientific facts, I am inclined to give the preference to the inductive method as a means of education: — and I do this chiefly from this consideration — in this method we build up gradually and slowly, each mind as it acquires knowledge independent on itself for what is already acquired, and so the result is likely to be specially sound, and so pre-eminently conclusive to that habit of mind which I have set forth as the chief aim of education to educe. —

Deduction, as you will have seen, in the natural order of knowledge, follows induction. The general law is acquired from particulars, and other particulars may then be referred to it: — but as you have not to think out scientific truths for yourselves, but only to enter in upon the labours of others, a contemporaneous use of the inductive and deductive methods, is in your case, both possible and desirable; — it is the part of an instructor, from his own store of knowledge to bring forth and explain so much of the higher truths and scope of a science as shall suffice to stimulate the learner to work on through what may at first-sight seem but dry and weary details, towards more interesting and practical portions of a science, — at the same time avoiding so to state great and general truths that a pupil may catch but their expression, or a vague ideal, without mastering them through the upward course of induction from fact and experience. Just as in the study of language it is usual to begin with the declensions of substantives, and the conjugations of verbs if any sound knowledge of the structure of a tongue is to be acquired: — and yet to persevere solely through all grammatical rules and precepts without any gradual of those acquired to language, would be a toil beyond human patience. The inductive method then supplemented by the deductive, we will take as our mode of procedure, — and will at once proceed to consider its several steps illustrating them by some of the sciences in question. I left you to take on faith my assertion that the investigation of physical science required the severest care in examining and testing evidence before us, and was consequently a specially valuable instrument in educating our faculty of discrimination and judgment. Observe the proof of my assertion in the sequel.

The first step in induction is observation: — we must observe facts and phenomena before we infer anything concerning their uniformities. „In the first place", — (I a note the words of a great scientific thinker Dr. Whewell), — „to the formation of science, two things are „requisite, facts and ideas, observation of things without, „and an effort of thought within; or in other words sense „and reason: neither of these elements, by itself, can con- „stitude substantial general knowledge. The impressions „of sense unconnected by some rational and speculative „principle, can only end in a practical acquaintance with „individual objects; — the operations of the rational faculties, „on the other hand, if allowed to go on without constant „reference to external things can lead only to empty ab- „straction and barren ingenuity. Real speculative knowledge „demands the combination of these two ingredients, — „right reason, and facts to reason upon. It has been well „said that true knowledge is the interpretation of nature, „and thus it requires both the interpreting mind, and nature „for its subject, both the document, and the ingenuity „to read it aright." — These sound at first but as dry words, but they are pregnant with meaning: — it is useless, as the history of all science tells us, to form speculations without experience of facts: — it is equally useless to accumulate facts without the intelligence to generalise them. What would be the use of repeating, in parrot-like voice, the fact that there was a universal law of gravitation, without being able to infer from it that stones when thrown into the air fall, — that bullets fall, that boards fall, if we could not proceed from these particulars to any general truths, — that there is a law of gravitation. —

The first guide then of the intelligent student must be

experience. But what experience? A man or a boy must not go listlessly about the world observing in a passive way that which comes before him, and taking for observation the crude speculations of others.

„Experience", — says a learned chemist, — „must „not be mere experience of experiment, it must be the „active experience of experiment: i. e. one must not „only carefully examine phenomena as they spontaneously „present themselves in the ordinary course of nature, we „must purposely contrive, and vary circumstances, in order „that we may observe them."

As an instance of what I mean the astronomers of old observed that day after day the sun was on the east of the earth in the morning, and on the west in the evening, from this experience they inferred that the sun made a diurnal revolution round the earth, rising in the east, and setting in the west. The circumstances it is true were not such as could well be varied, for a man could not ever behold the earth's motions from a distance, yet the thought of Galileo devised a means by which he could investigate the positions of the sun and earth, not simply in their abstract relation to each other, but in relation to their position and course relatively with that of the other heavenly bodies. His conclusion was that the earth moves round the sun. Now this is what I mean by intelligent and not passive observation. In like manner the unquestioned experience concerning inorganic matter produced the absurd and superstitious figment of Alchemy. Every one of the sciences which you are about to study will affort similar examples of the absurdities of careless and crude conclusions from experience. Here then is our first and fundamental step in the inductive method.

I have said that experience however correct is of little use without generalization, or the systematic combining of singular observations. This, viz. generalization, is our next step: and as its sequel classification. It is possible for us after collecting instances to group them on the most foolish and useless principles — as if we classed and generalized animals as large, small, and middle-sized: or minerals as black, white, green, etc. The principles on which we classify individuals must be an intelligible one, and based upon some natural distinctions. I cannot here enter upon the question whether there are absolute natural classes and divisions on some bases which may clearly be recognised in nature. I will give you instances of good and bad classifications or generalizations from the physical science.

There is perhaps no science which has gone through so many phases of generalization as that of Zoology. — To begin with, — Aristotle saw a great natural division, as he thought, between animals with red, and colourless blood, and consequently he roughly divided them into these two classes. It was soon found that for practical purposes this classification was a meagre, and in one sense a confused one, for many animals coming under the one class had some of their most important organs in conformity with those of the other. Linnaeus believed that he had at last read the book of nature aright when he pronounced in favour of the circulatory system, as a natural basis upon which all animals can be gathered into general classes. He accordingly made three classes under which every known animal could be brought: —

(I) Those containing warm red blood: and provided with a heart containing four compartments: two auricles, and two ventricles. (II) Those possessing red and cold

blood: with a heart, one auricle and one ventricle. (III) Those with cold, white sanies, and no blood. —

Hunter, not content with this fundamentum divisionis, tried several, varying them according to the purpose for which he used the classification: e. g. digestion, heart, respiration, generation, and nervous system.

Cuvier divided them into four classes according to their nervous systems. — And, lastly, we have perhaps the most useful classifiation according to the vertebre of animals into five heads: — viz. Fishes, Amphibia, Reptiles, Birds, and Mammals, and one which is based on sounder and more complete interpretation of nature than any of its predecessors.

As an instance of the importance to be attached to this step in induction, I will instance one more physical science in which classification has ployed a very important part: I allude to Botany. The earliest system which we get is the Linnaean. — Linnaeus according to the stamens and pistils possessed by plants classified them in an artificial and very arbitrary manner into twenty four classes under each of which there were from one to seven orders, and under these again sub-orders. The reason of classification was not one deeply rooted in the nature of plants, indeed the pistils may be considered as almost accidental properties; and consequently this system was barren of fruit, it enabled man to recognise the name of a plant, but nothing more, — none of its important properties, its powers of healing or destroying life. On the contrary the author of some of our most scientific botanical works gives his ideal requisites of useful botanical classification: — „Systematic Botany", he says, „is the science of arranging plants in such a „manner that their names may be known, their affinities

„determined, their true place in a natural system fixed, „their sensible properties judged of, and their whole history „elucidated with certainly and accuracy: anything short of „this is not a history, but an artificial scheme." I need not remind you that the Linnaean system has now given way to one whose primary general classes, are three clearly defined, distinct, natural types. These instances which might be parallelled by similar ones from all the physical sciences will have been sufficient to indicate the great importance of a sound basis of generalization.

It will not be enough in a scientific induction to have sound reasons for our generalization: — we mount up from one generalization to another, and pile class upon class, and it is impossible for our unaided memory to picture at our bidding these great schemes for us. — Generalization must be followed by charts, if our method is to be practical.

In these we must put down the particular instances, and unite them into general classes by brackets, and these again into more general, till we have a perfect table of a science, mapped out as the chart of rivers of some country. This is not only a great aid to memory but also a great safeguard against arbitrary and absurd classification, for under each heading there must be noted some reason for the combination of individuals or instances. For example suppose we had charts side by side of the sciences of Physiology and Chemistry.

Physiology you know „is the science which treats of „the properties of organic bodies, animal and vegetable". Chemistry that of inorganic. — Now at the bottom of the chart of inorganic bodies we should find fifty two primitive substances: — at the bottom of that of organic bodies we

should find eighteen, all of which are also among the fifty two. Our first impulse would consequently be to map out the science of organic simply as a portion or branch of the study of bodies whether organic or inorganic: but if we looked a little higher up these charts we should at once see that for several reasons stated in the classification these sciences were perfectly distinct, such as this, that in the case of organic products the combining properties of the elements do not observe arithmetical ratio, which is always observed in the case of the inorganic. Or this, that in the inorganic two elements can alone combine, and then this mixture be joined with a third: — while in the organic several elements can at once unite co-ordinately. In these cases you see the great use of a well drawn up chart of each science.

This process patiently and intelligently pursued might give us a perfect acquaintance, at least as far as human knowledge is perfect, with any of the physical sciences. Its whole matter should now be laid out before us, „veluti descripta tabella", and any singular instance brought before us, at once referable to its proper position. —

Deduction, I said, is only the converse of the inductive process. As we have mounted up this ladder from single instances to the broadest laws and uniformities, so we can descend by it, gradually unfolding the many particulars deducible from each general instance. This is the most perfect stage in a science, that which can only be used by a teacher highly skilled in the whole science, or drawn from a perfect chart. Now, few sciences are perfect: i. e. in nearly all more and more general laws remain to be discovered, and are daily being discovered. But in proportion as sciences become more perfect, deduction becomes

easier: and it is also possible from any attained point in a science; hence its use to an instructor. Not by any means to make a pupil learn a quantity of general unverified, and consequently incomprehensible rules, but to explain observed facts by drawing them from their isolation under heads already made, and so obviating the tedious process of constantly hunting after instances with which to compare the result of each new observation. —

I will draw but one conclusion from this survey of scientific method. It is often argued against the study of several branches of science, as we are now entering upon it, that it is likely to lead to superficiality of mind, in other words, that you are likely to know something about each of them, but not much about any one. But observe that there is a very great difference between knowing a little about many things, and knowing that little superficially. The very object of this method in scientific study is to prevent superficiality, which consists in unsystematised and desultory information. You can not possibly know anything about any one science, without a scientific method: and with it you may most easily learn all the leading facts of all sciences of a similar kind. The formula given it is equally easy to fill it up with zoological, botanical or chemical facts.

It points out to you where are the broadly drawn lines which divide phenomena naturally, and where we are to look for their distinguishing characteristics. This done, it does not require any very extraordinary intelligence to fill in the space with given facts.

The student of Zoology, who has pursued his investigations on a scientific method, will very easily become a proficient in Physiology or Chemistry. — I have tried to

set before you the great aim and end of education: and its practical requirements, and importance to each one of us. That it is no mere temporary discipline soon to be discarded for happier freedom, but the beginning of a life which is an almost unbroken whole, and that consequently habits of mind now acquired for good or for evil will be permanent and indelible. I have next offered to your patient consideration my reasons for thinking these physical sciences, upon which we are now entering, as the best means of education in your case, not only on account of the mental habits resulting from them, but also from their practical use, and all-absorbing interest. Further, I have, as clearly as I have been able, pointed out a method by which I think they may most easily and most thoroughly be acquired. —

Beyond this all is in your own hands. — I might have given this one more argument in their favour, — their practibility as subjects of self-education. — Nature is never a sealed book. The matter for investigation in these sciences is not laid by in dusty and crabbed volumes. It is all, and ever around you, and so its study is specially fitted to be, not that of boyhood alone, but of a life time.

I trust that you may begin it earnestly now, while you have much time, and while its results may be of such high advantage, both to your success in your several professions, and to your happiness, and enlightenment of mind. —

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