VIRCHOW ON THE TEACHING OF SCIENCE.[1]

THE jubilee meeting of German naturalists and physicians at Munich last year (1877) was marked by an incident which has deservedly attracted attention in this country. Addresses were delivered to the Association, among others, by three very eminent men, and, as was natural on such an occasion, each of them took the form of a review of the situation of science at this moment. Häckel, of Jena, led the way by a discourse on the present position of the evolution theory; on the nature of the evidence for various parts of it; the bearing of it upon mental science or psychology, upon education, and upon morals. He was followed by Nägeli, of Munich, 'On the Limits of Natural Knowledge,' who pointed out that we have a limited number of senses, and that we cannot deal with things which are too large, or too small, or too far away, or with events which happened too long ago; but that if we will be satisfied with such kind of knowledge as we can get, we do really know something, and may come to know a great deal more.

But the words most listened to and most repeated were undoubtedly those of Virchow, of Berlin, 'On the Liberty of Science in the Modern State.' He recalled the early days of the Association, when it had to meet in secret for fear of the authorities; and he warned his

[1] *Nineteenth Century*, April 1878.

colleagues that their present liberty was not a secure possession, that a reaction was possible, and that they should endeavour to make sure of the ground by a wise moderation, by a putting forward of those things which are established in the sight of all men, rather than of individual opinions. He divided scientific doctrines into those which are actually proved and perfectly determined, which we may give out as real science in the strictest sense of the word; and those which are still to be proved, but which, in the meantime, may be taught with a certain amount of probability, in order to fill up gaps in our knowledge. Doctrines of the former class must be completely admitted into the scientific treasure of the nation, and must become part of the nation itself; they must modify the whole method of thinking. For an example of such a doctrine he took the great increase in our knowledge of the eye and its working which has come to us in recent times, and the doctrine of perception founded upon it. Things so well known as this, he said, must be taught to children in the schools. 'If the theory of descent is as certain as Professor Häckel thinks it is, then we must demand its admission into the school, and this demand is a necessary one.' And this, even although there is danger of an alliance between socialism and the doctrine of evolution.

But, he went on to say, there are parts of the evolution theory which are not yet established scientific doctrines in the sense that they ought to be taught dogmatically in schools. Of these he specially named two: the spontaneous generation of living matter out of inorganic bodies, without the presence of previously living

matter; and the descent of man from some non-human vertebrate animal. These, he said, are problems; we may think it ever so probable that living matter has been formed out of non-living matter, and that man has descended from an ape-like ancestor; we may fully expect that evidence will shortly be forthcoming to establish these statements; but meanwhile we must not teach them as known and established scientific facts. We ought to say, 'Do not take this for established truth, be prepared to find that it is otherwise; only for the moment we are of opinion that *it may be true*.'

There is something, I think, very natural and very charming in this scene. The young apostle is full of faith and hope, he has fought his way, undaunted by little stumbles and disappointments, through great morasses of difficulty, and always he has seen his gospel steadily marching on to its triumphant subjugation of the ideal world; and before this gospel accordingly he summons the practical world to bow down. 'Not so fast,' says the veteran, who, in his time, indeed, has been bold enough, and taken sober men's breath away; but who now marches with careful steps, and is conscious of his balance. 'Don't be quite so sure about it; you will turn everything upside down.' One is glad that on a great occasion both sides had their say, and that the word of caution came last, being prompted by the word of courage; and one hopes that on all similar occasions there may be courage enough to justify a like word of caution.

It is also very natural that this speech should have been a source of great relief and comfort to many who did not want to believe in the doctrine of descent, and

who feared that, somehow, they were going to be made to believe in it. It seemed to them, in Dr. Tyndall's words, that 'the world—even the clerical world—had for the most part settled down in the belief that Mr. Darwin's book (*The Origin of Species*) simply reflects the truth of nature;' and that, on the penalty of appearing somewhat singular, they would have to settle down in the same belief themselves. But here is a very eminent scientific man who says he is not quite sure about it; so the world, having only settled down under the supposed weight of an authority which it is not yet very fond of, begins to unsettle itself again; and one need not be at all singular in saying that there is really nothing in the doctrine of evolution, because it is not yet supported by facts. Indeed, the world has become so much impressed with the importance of the rule that you should not teach as a known fact that which is not a known fact, that we may almost expect to hear a bishop declare from his cathedral pulpit that the authorship of the Fourth Gospel is a doubtful question, and that a man would be rash who fully made up his mind to ascribe it to the apostle John.

It may therefore not seem amiss in one who is no biologist, who is therefore a layman in regard to this question of organic evolution, if he should endeavour to lay to heart the warnings of Virchow, and inquire what practical bearing they have on the state of things in our own country. This is what I now propose to do; but I shall confine myself in the main to the question of school teaching. I speak as a householder to householders, on this matter of grave and common concern: what shall we have taught to our children?

Of all the questions discussed in Virchow's speech, this seems to me the most practical, and the most interesting to us as a people.

For I do not think that we in England have much cause to fear either a reaction which shall stop the mouth of the scientific teacher, or a socialist revolution founded on the doctrine of descent. It is true that there are some among us who seriously dislike 'science,' and who look with dread and suspicion on the teachers of it. I am not attaching importance to the personalities of orthodox polemic, which, having 'no case,' is compelled to 'abuse the plaintiff's attorney.' This symptom is of weight only as a symptom, and as such is understood by the intelligent public. But there are men high in literature, in statesmanship, and in art, whose good opinion, founded on knowledge, every man of sense must count desirable, who yet withhold that good opinion from the scientific teacher and the work that he is doing. Notwithstanding this fact, I have no fear that the attitude of mind of these men will be intensified, or will become more general; because it seems to me to be clearly traceable to two circumstances, both of which are disappearing. I mean that there are faults on both sides, and that both faults are being mended.

The first fault is on the side of the scientific student; and yet it is not altogether *his* fault, because it comes of the great change which is passing over our educational system. We have all been learning science—that is, organized common sense—at school for some centuries, and did not know what it was. But of recent times our science has received enormous additions,

partly new sense, partly fresh organized; and these have now to be taught. The first generation of teachers of the new science could naturally not learn it in places where the old science, which we called a liberal education, was to be learned. Some of them learned both, with much labour, and searching, and picking up out of stray corners; but some went without a liberal education altogether. And perhaps a few of these, when they found what a demand there was for them and how important they were, may have fallen into a mistake, and taken their half- or quarter-culture for a whole culture. Now when a man not only mistakes his half- or quarter-culture for a whole culture, but thinks that the culture which he does not possess is silly and worthless, then people who have received a liberal education are apt to think him a bore. And it would be a hard matter to prove them altogether in the wrong.

But this race, which bores a few and educates the many, is patiently and surely exterminating itself. As the new science makes itself at home in the school-house of the old, as it is more taught and in a more civilized manner, the mind of the student balances itself, and recovers its sense of proportion. Exact observation goes naturally enough with justice and simplicity of statement; the great inductions of human life and feeling lighten up by resemblance and contrast the great inductions of physics. Dynamics and Prose Composition have met together; Literature and Biology have kissed each other. Perhaps not yet, but the good time is coming. And in that time every scientific teacher will have received such a many-sided culture, and will be no longer a bore to anybody. Above all, he will

have studied that History of Culture itself, which is the great unifier and justifier and purifier of all our teaching.

The other fault is on the side of those who dislike the new science; it is the fault of being profoundly ignorant of it. No public school boy thinks a man uncanny because he knows a great deal of Greek; no member of Parliament imagines that a careful study of ancient history, or even a revolutionary view about the *Iliad*, might become a dangerous ally of socialism. It is because he has learned a little Greek himself, and knows what it is like. But if a man has morphology at his fingers' ends, or is profound about organic radicles, that is a man to beware of. There is no knowing what theories he does not secretly foster. Or else he is a mere impostor, and gets a great reputation for pottering away at some silly trifles, being really no better than an official in the Herald's Office: so hinted some irreverent young scapegrace in the prologue to the Westminster Play. Now it is clear that a statesman who thinks a decimal coinage means the keeping of shilling and pence accounts in terms of decimal fractions, or a musician who really sees no difference between Graham Bell's telephone and Wheatstone's telephonic concert, may well be expected to misjudge exact students, and their studies, and their aims. But in the good time coming, when 'there shall be no Member of Parliament who does not know as much of science as a scholar in one of our elementary schools,' when also benevolent old ladies may be expected to know one end of a guinea-pig from the other, all this will be changed. The man of science will be no more uncanny than the

Greek scholar is now. And we may be quite sure that the average Englishman is not going to see a man bullied for merely knowing a little more of what he himself learned a little of at school. When he has learned a little science himself, and knows what it is like, he will have, it is true, a less superstitious reverence for the authority of the investigator; but then also he will regard him as a citizen, having as good a right to be trusted and respected, and to say his say upon matters of common interest, as anybody else.

Such distrust or dislike of science, then, as is to be found among us, is due to circumstances which are rapidly disappearing, to misunderstandings and imperfect training, and not to that which alarmed our Prussian colleague, a tendency in the expounders of scientific doctrine to make too sure of things, to put forward as known fact that which is not yet known fact, but only conjecture. Indeed, our own scientific teachers, notably Huxley and Tyndall, have for years been impressing upon us this very thing, by example and precept, in season and out of season—if indeed it is possible for such warning to be out of season. And to their testimony I shall hope to return presently.

As to that other fear of Virchow's, that some caricature of the true doctrine of evolution may become a dangerous weapon in the hands of the socialist, it is a thing somewhat difficult for us to understand. We have a way of suspecting that when socialism is dangerous, somebody or other is being badly treated. We can conceive that it should cause uneasiness to a repressive and meddling protectionist Government. But in this country, where it would probably mean a kind

of alliance between co-operative stores and that very respectable institution, the Metropolitan Board of Works, we cannot undertake to be much alarmed about it. Before any socialist measure could enter into practical politics at all, it would have so far to commend itself to the country as to be supported by a considerable number of votes in the House of Commons; and a measure which can do that is a thing not to be shuddered at, but to be calmly discussed.

What really remains for us to consider, then, as of English interest, is, as I said before, that question about the teaching of our children. The principle laid down by Virchow I shall assume as the basis of the discussion: *we ought not to teach to little children, as a known fact, that which is not a known fact.* And the questions to be discussed are, in what respects this canon is disobeyed or in danger of being disobeyed: and what means we should adopt that our system of teaching may be more perfectly conformed to it. It seems to me that the second question answers itself in the process of considering the first one. I shall therefore now proceed to those doctrines which, in Virchow's view, are in danger of being taught with an assurance which is in advance of the actual evidence for them.

And first, let us consider that very important doctrine of the descent of man from some non-human ancestor. 'There are, at this time, few students of nature who are not of opinion that man stands in some connexion with the rest of the animal world, and that such a connexion may possibly be discovered, if not with the apes, yet perhaps, as Dr. Vogt now supposes, at some other point.' Notwithstanding this, Virchow says:

'We cannot teach, we cannot pronounce it to be a conquest of science, that man descends from the ape or any other animal.' He bases this decision upon the absence of such evidence from palæontology in the case of man as is found in the case of the horse. The horse (asses and zebras being included under this name) is a one-toed beast, thereby differing from all other mammals; but, as he has many points showing relationship with them, it is probable that he is descended from a five-toed ancestor. The problem is to find this ancestor. There is no trace of him in the quaternary strata. If the naturalist were confined to the evidence of those strata, and were not particularly careful of his logic, he might 'declare that every positive advance which we have made in the domain of prehistoric hippology has actually removed us further from the proof of such a connexion.' The doctrine of the descent of the horse from a five-toed ancestor would, in fact, rest upon other grounds than the actual discovery of the ancestral form. But the ancestor of the horse has been found in the tertiary strata. He has three toes in the more recent strata, and four toes in the earlier; and, curiously enough, the complete series is found in America, where there were no horses at the time of its discovery by Europeans. Now Man, on the other hand, is a complex-brained animal, differing in this way and in some others from all other mammals; but since in other respects his whole structure shows relationship with them, and especially with the apes, it is probable that he is descended from an ancestor with a simpler brain and a structure generally bearing more resemblance to the common Simian type. The problem is to find this ancestor.

There is no trace of him in the quaternary strata, because the quaternary men are still men so far as their bony structure is concerned, and we have no evidence about the complexity of their brains, the pointedness of their ears, or the hairy covering of their bodies. Nor, as yet, has any decisive discovery been made of the remains of man, or of any sufficiently man-like animal to count as his ancestor, in the tertiary strata. Until we find the missing link, says Virchow, the descent of man from an ape-like ancestor is not a conquest of science. When we do find the missing link, it will be a conquest of science.

It will naturally, I think, strike anyone who, though a layman, has gained a certain amount of secondhand knowledge of this subject from books, that in this view of the two cases the evidence of fossils is made rather too much of, while other kinds of evidence are wholly ignored. It is a bold thing to criticise the judgment of a pathologist upon general doctrines of biology, when one is oneself not a biologist in any respect. I will therefore shelter myself under authority.

'When we confine our attention to any one form (says Darwin) we are deprived of the weighty arguments derived from the nature of the affinities which connect together whole groups of organisms—their geographical distribution in past and present times, and their geological succession. The homological structure, embryological development, and rudimentary organs of a species, whether it be man or any other animal, to which our attention may be directed, remain to be considered; but these great classes of facts afford, as it appears to me,

ample and conclusive evidence in favour of the principle of gradual evolution.'[1]

For example, it happens that the missing link between man and the anthropoids has not yet been found; but there is a Miocene link which bridges a greater gulf between two other families of apes.[2] So that kinds of evidence may exist in regard to an order of animals which are wanting in the case of an individual family of the order. But both the general analogy of Nature, and the three great classes of facts considered by Darwin in the special case of Man, are apparently reckoned by Virchow as of no practical weight, until the bones of the missing link are safe in the glass cases of a geological museum. I say *apparently*, because it would be insulting a great man to suppose that he really held such an opinion, which, moreover, is inconsistent with the preface to the English translation of his speech. In fact, this admirable speech, in so many ways like that of a cabinet minister reassuring his Opposition, contains more than one passage which, especially when isolated and printed in capitals, it is easy for the Opposition to interpret in a sense more favourable to its own views than that which the speaker had in his mind.

Not only, however, are important kinds of evidence left out of count, but as it seems to me—under guidance, as before—the cogency of the evidence from fossils is somewhat overrated. We must be very careful not to be too sure of these conclusions, lest we should teach as established results of science what are, after all, remote and precarious inferences.

[1] Preface to *Descent of Man*.

[2] *Descent of Man*, i. 197.

'We must recollect (says Huxley) that any human belief, however broad its basis, however defensible it may seem, is, after all, only a probable belief, and that our widest and safest generalizations are simply statements of the highest degree of probability. Though we are quite clear about the constancy of the order of Nature, at the present time, and in the present state of things, it by no means necessarily follows that we are justified in expanding this generalization into the infinite past, and in denying, absolutely, that there may have been a time when Nature did not follow a fixed order, when the relations of cause and effect were not definite, and when extra-natural agencies interfered with the general course of Nature.'[1]

The fact is, we are not absolutely and theoretically certain that these old three-toed and four-toed horse-bones were not made, on purpose to deceive us, by the devil; himself, according to Cuvier, a horned and hoofed, and therefore graminivorous animal, with more than one toe on the hinder limb.[2]

This kind of tangible evidence, which gives us something definite to lay hold of, is peculiarly apt to produce conviction without being properly understood. 'Is it really true that our horses are descended from an ancestor with three toes, who lived a long time ago?' 'Why, of course it is; here's his hock.' It is something like what occurs in the stage-plays, when somebody rushes in to the hero, and says: 'Take these papers and guard

[1] *American Addresses*, p. 3.

[2] The devil is said to have appeared to Cuvier and threatened to eat him. 'Horns? Hoofs?' said Cuvier. 'Graminivorous. Can't eat me.' 'All flesh is grass,' replied the devil, with that fatal habit of misapplying Scripture which has always clung to him.

them carefully; they prove that you are a prince.' The sight of the bundle neatly done up in red tape produces conviction in a moment. But we subsequently reflect that it may be a somewhat delicate and difficult matter to prove by the aid of papers that a man is himself or anybody else; and that there are other methods of establishing personal identity, which are not less valid in the courts.

I am not disparaging this palæontological evidence for the descent of the horse, or saying a word inconsistent with Huxley's conclusion that it is demonstration, in the only sense in which demonstration can apply to an historical fact. What I wish to point out is that it contains many steps of reasoning which are rather difficult to the apprehension of anyone who is not a specialist, and which involve considerations somewhat abstract and remote from the tangible facts on which they are founded. The succession of strata in time, and the mode of their deposition, especially the relations of European strata with American; these, and some other doctrines of geology, are involved in the argument. Now, however certain they may be, the evidence upon which they are established is circumstantial and remote. It is easy enough to the geologist, who is accustomed to it, but it does require special study to master it fully. And there is no trace whatever of these difficulties in the statement 'Here's his hock.' Convincing as that statement is, it does not carry along with the conviction a fair estimate of the evidence on which it is based.

With this consideration in mind, let us compare again the evidence for the descent of man with that for the descent of the horse. The generation of men of

any given race now existing is descended from parents who on the average differed imperceptibly from themselves. This has not gone on for ever, because physical evidence proves a beginning to the present state of the earth. Were the first men also the offspring of parents who differed imperceptibly from themselves, yet so that the imperceptible difference came just where we draw the line between man and not-man? Such a line would of course be arbitrary, but we may suppose a certain hundred generations, the change in each being imperceptible, but still such that we should call the first not-men and the last men. This is the supposition of a non-human ancestor, as made by the evolutionist. If this supposition is rejected, the first men may have originated (1) from parents differing largely from them in structure; (2) from non-living matter, or (3) from non-existence, being men from the moment they began to be. We are not bound to make any supposition at all about the origin of the first men; but if we do make any supposition, it must be one of these.

Suppose, however, that we want not merely to make a supposition, but to infer from the facts before us what actually happened. Then we must make the assumption that there is some sort of uniformity in nature. Without this we cannot infer at all, for inference consists in transferring the experience which we have had under certain conditions to events happening under like conditions, of which we have not had experience. It is true that we cannot be absolutely sure of the uniformity of nature, or that our present conception of it is right: but still it is the only thing we have to go upon. Human knowledge is never absolutely and theoretically

certain, but a great deal of it is practically certain, which is all we want.

Now the production of man from non-living matter, or the coming of any kind of matter into existence out of nothing, are things so entirely without parallel in our existing experience that we cannot infer them unless our experience entirely changes its character. If clay or mould would form itself into a human body a few times, we might learn something about the conditions under which such a transformation takes place, which would enable us to infer that it had taken place before. If matter would occasionally come into existence out of nothing, we might say what kind of matter was most likely to do such a thing; whether buttons or sovereigns were most gifted with this faculty, and so on. But even so, some time must elapse before we could infer, because our whole conception of the order of things would be turned topsy-turvy.

If, therefore, we are to infer anything at all about the origin of the first men, we must infer that they descended from non-human ancestors. What sort of ancestors these were, is, in the present state of knowledge, matter of conjecture merely. To guide this conjecture, we have 'the homological structure, embryological development, and rudimentary organs' of existing men. The evidence of this kind set forth by Darwin seems to point with very great probability to an ancestor more ape-like than man. Still these indications are not so clear and unmistakable that a *less* ape-like ancestor, as Vogt supposes, would be inconsistent with the uniformity of nature. We are dealing with a long series of similar events, the descent of each successive generation

from one very like it; and though each event is an example of what occurs habitually in our experience, yet the effect of the whole series of such events is something of which we can only get knowledge by means of palæontological evidence. We can only, therefore, infer with a very moderate amount of probability that men are descended from this sort of animal or that sort of animal. *This* is the point which will be set at rest by the missing link. But I venture to think that the evidence for the descent of man from *some* non-human ancestor will be but very slightly strengthened by that discovery; and that it is now not perceptibly less cogent than that for the descent of the horse.

For observe that each alike depends on the assumption of the uniformity of Nature. That being given, the descent of man follows from the originally fluid condition of the earth, proved by physical observation and reasoning. Failing that, the evidence for the descent of the horse vanishes into thin air. It is not the least bit more likely that man arose out of the dust of the earth than that the devil made the American horse-bones. Worse than this, quaternary man goes too. 'Quaternary man,' says Virchow, 'is no longer a problem, but a real doctrine.' But how do you know that the devil did not make the fossil men and all the flint implements? This also is quite as likely as that a human body was ever formed by the direct transformation of non-living matter.

'Well then,' I hear my anxious friend say, with a sigh of relief, 'we need not believe even in the antiquity of man, or the evolution of horses. They are all doubtful together.' My good soul, no student of science wants

you to believe anything unless you understand the nature of the evidence for it, and then only to the extent which is warranted by the evidence. There is no occasion for you to form an opinion about these questions. You need have no fear of being singular. There is always the defence of the ensign who was asked if he had seen *Punch*: 'Well, you know, the fact is, I am not a reading man.' But if you wish to form an opinion, there are many excellent manuals in which you may learn the nature of the evidence and the methods of reasoning on which such an opinion should be based. If your opinion should be adverse to the views held by other scientific students, you will do great service by stating your objections. Do not suppose for a moment that we want you to believe on any other terms.

But what we do hope, for your sake, is this: that you will not allow any dishonest person to persuade you to *dis*believe strongly in the doctrine of evolution, because Virchow has admitted that certain parts of it are not yet absolutely proved. It is one thing to believe that a doctrine is false, and quite another thing to admit a theoretical doubt about it.

I say a *theoretical* doubt, because it is a doubt founded on the necessary imperfection of all human knowledge, and not on any practical defect of the evidence. For a doubt precisely similar in kind, though rather greater in degree, attaches to the statement that the Russians took Plevna last year. The evidence for the truth of this statement is, I admit, very strong, and I suppose no sane man would be disposed to question it for a moment. We have the testimony of all the newspaper correspondents, the course of subsequent events, the special

information of the Government, and literally a whole army of witnesses besides. Still, the Russians may have been one and all under a continuous hallucination, and be even now in imminent danger from Osman Pasha. Or those rascally papers may have laid their heads together to deceive the whole British nation, down to this hour. Either of these suppositions is a great deal more likely than that the devil made the old horse-bones, or that clay was transformed into a human body. To be sure, they contradict our experience of the uniformities of human action to such an extent that we cannot seriously entertain them. But the uniformities of human action are known with far less accuracy and completeness than the uniformities which characterize the generation of living bodies. One man under an hallucination is common enough ; one newspaper wrong in its facts is well within our experience. So that we have something to go upon in conceiving a widespread delusion. But a man without any mother at all, a real son of the soil, is a thing our experience gives us no help towards conceiving.

If you went to a man of the world with this doubt about Plevna, urging upon him that newspapers were often mistaken, and begging him to consider it in buying stocks, he would either take you for a lunatic and humour your fancy, or he would say: 'Don't be so silly ; I have no patience with you.' But the student of science is obliged to have a great deal of patience, and desires to have more.

It seems, then, that the difference between the doctrines of the descent of horses and of the descent of men is not that one is a known fact and the other a con-

jecture, because each of them is practically as certain as such a doctrine can be, though subject to the theoretical doubt which attaches to all human knowledge. And yet there certainly is a great difference between the highly abstract and general considerations which go to establish the one, and the more concrete, but still rather difficult, arguments which prove the other. The evidence in the two cases appeals to two different classes of minds. The inference from a modern horse-bone to the horse whose bone it was is a tolerably easy one, which can be brought home to many minds. From a fossil bone to the ancient animal is a more remote inference, which was at first made with considerable difficulty ; yet still any person of ordinary intelligence may be expected to grasp it. Then the geological inferences, from stratified rocks to the sea or river which deposited them, from successive position to successive age, and so on, may have their way smoothed by concrete examples so as to carry their due weight without much mental strain. The biological inferences which connect the modern horse with his fossil representative, based on the structure of corresponding parts and the development of the colt, involve reasoning of a rather more abstract kind. But the whole of this evidence may be fairly presented to a mind which is still incompetent to form that general conception of the uniformity of nature which makes the directly inorganic origin of man a supposition not to be seriously entertained for a moment. To grasp the idea of any law of nature requires a considerable effort of abstraction, and that the idea may be of any real use it must be founded on acquaintance with the facts that come under the law. The general con-

ception of law which is contravened by the supposition in question has to be abstracted from a knowledge of many different laws, dynamical, physical, chemical, biological. This conception, therefore, implies a very wide and many-sided training in facts, a very deep and thorough training in logic, as its foundation. Much education is required to enable the learner really to estimate the evidence for the many-toed horse; much more is wanted for the clear comprehension of the evidence for the simpler-brained man.

Here the education question, which has been underlying our whole discussion, is brought to the front. It is clear that the evidence for these doctrines cannot be taught until a late period in education. What are we to do in the earlier periods? Shall we say: 'Horses had three-toed and four-toed ancestors; by-and-by you will learn how this was found out. We think, but are not quite sure, that men had simpler-brained ancestors; by-and-by you will learn why we think so'?

It seems to me that this is the very worst thing we can do; that if we say this, we shall not only confuse the child's head at the time with abstractions which it is impossible that he should really grasp, but we shall effectually prevent him from learning them properly in the future. The true rule, I believe, is this: *Before teaching any doctrine, wait until the nature of the evidence for it can be understood.*

This appears at first sight a very hard thing to do. Yet it is really involved in Pestalozzi's great principle that children should be made to find out things for themselves. To make clearer the reasons for it, I will consider a case which has the advantage of not being at

the present moment in controversy; the case of the teaching of chemistry. Suppose we were to begin teaching chemistry by saying that carbon is made up of atoms which have four hooks or hands by which they can hold on to other atoms; that oxygen atoms have two hooks, and hydrogen atoms one. Consequently we can hook two hydrogen atoms to an oxygen atom, and this makes water; or we can hook two oxygen atoms to a carbon atom, making carbonic acid; or we can hook four hydrogen atoms to a carbon atom, making marsh-gas. Then we should utterly confuse the learner's mind, and prevent him from learning chemistry afterwards. These statements belong to the doctrine of atomicities. Nobody doubts that these statements represent, in highly metaphorical language, real facts of chemical action; only Sir Benjamin Brodie says that since the hydrogen atoms occur always in even numbers in compounds made of carbon, oxygen, and hydrogen, we ought to fasten them together in pairs, and call each pair an atom with two hooks. What sort of thing we should find, if we knew all about these atoms, answering to the metaphor of the hooks, nobody knows. Without a knowledge of the facts which they symbolize, these statements are mere useless nonsense in anybody's mind. They are worse than useless; for they make him think he knows the facts, and so prevent him from really getting to know them.

On the other hand, we may follow Dr. Williamson's method, show the children how to make carbonic acid, and then pour it on a candle to put it out; burn hydrogen to produce water, and so forth. When a few of the commoner substances are real things to them, whose

properties they are familiar with, they may learn to weigh and measure. Then the law of definite proportions becomes legitimate teaching, and the law of gaseous volumes. It is only necessary to verify these in a few cases, that the *nature* of the evidence for them may be understood.

Here arises a typical question. How, at this point, shall we deal with the doctrine of molecules? The chemical evidence for it may now be clearly understood; but the chemical evidence leaves it still a hypothesis. It becomes quite clear that the hypothesis explains the facts, and links them together: but it does not become clear that no other hypothesis will explain the facts. I think there is every reason why it should be taught *as a hypothesis*; there are materials in the pupil's mind for estimating the value of the hypothesis in making the facts clear to him, and also for understanding why, at present, it is *only* hypothesis. And I further think that, at this stage, no great harm will be done by telling him that when he has learned enough about heat and motion, he will find the hypothesis turned into a demonstrated fact.

The doctrine of atomicities depends upon the various combinations of the same set of elements with one another. The facts on which it is based may be described without introducing any totally new conceptions; the *nature* of the evidence for it may therefore be understood by a pupil at this stage, without any further experiment. I am not, of course, speaking of the training of a specialist, but of that which should form a part of general culture.

Of these two methods of teaching, there can be no

doubt that the latter will commend itself to the common sense of every reasonable man. It insures that the pupil shall learn to *do* things, that is, either to deal practically with certain objects, or to use in thinking certain conceptions; not to think he knows things of which he is really ignorant. And all the time it cultivates a habit of accepting beliefs on the strength of the evidence for them, of preferring true and honest knowledge to sham knowledge. And it secures us against the teaching, as known fact, of that which is not known fact. The only danger in this respect is in the doctrine of molecules; and here we must impress very carefully on our teachers that they should not miss the important lesson in logic and in scientific procedure involved in the conception of a hypothesis, and in recognizing the imperfection of the evidence which fails to exclude all other hypotheses.

Now let us go back from this chemical doctrine of atomicities to the doctrine of evolution. In what form shall we have the doctrine of evolution taught to our children? Certainly not as a dogma to be accepted on the authority of the teacher, evidence for which may be forthcoming afterwards. Certainly not at all until our children are competent to understand the nature of the evidence for it. Certainly not, therefore, first in its most general form, and afterwards in special applications; but first in those special cases where the evidence is of the simplest kind, most closely related to the facts; and then, as a consequence of the comparison of these cases, the general doctrine may suggest itself.

Nevertheless, the teacher, knowing what is to come in the end, may so select the portions of various subjects

which he teaches at an earlier stage that they shall supply in a later stage a means of understanding and estimating the evidence on some question of evolution. He may, for instance, pay special attention to hands and feet when he is teaching biology, because these parts are of great importance in the questions of the evolution of the horse and of the relationship of man with the apes. Or in teaching sociology, which is all about papa and mama, clothes, houses, shops, policemen, halfpence, and such like, he may specially single out those points in which civilized folk differ from barbaric and savage folk, in order to prepare the way for the historic and pre-historic evidence which proves that we are a risen race and not a fallen one. In other cases the doctrine of evolution may guide the teacher in his methods. So much as the psychologist may already infer with safety about the evolution of mind, will lead him to found all abstract notions on previously formed concrete ones; to build his houses out of carefully made bricks, instead of trying to pull bricks out of castles in the air. And he will endeavour to give clearness and solidity to the dawning moral sense by leading to the easy observation that the affairs of the nursery or the Kindergarten cannot go on unless we tell the truth and let alone other folk's things. The affairs should of course be such that a failure in them would seem to the child a calamity too portentous to be thought about.

In fact, as Häckel says, the effect of the doctrine of evolution upon teaching and the methods of teaching cannot fail to be enormous and widespread, quite in-

dependently of the direct teaching of any portions of the doctrine itself.

Let us now go on to examine, in respect of their fitness for education, certain other doctrines mentioned by Virchow; taking next the doctrine of Spontaneous Generation.

'If you ask me (says Tyndall) whether there exists the least evidence to prove that any form of life can be developed out of matter independently of antecedent life, my reply is that evidence considered directly conclusive by many has been adduced, and that were we to follow a common example and accept testimony because it falls in with our belief, we should eagerly close with the evidence referred to. But there is in the true man of science a desire stronger than the wish to have his beliefs upheld; namely, the desire to have them true. And this stronger wish causes him to reject the most plausible support, if he has reason to suspect that it is vitiated by error. Those to whom I refer as having studied this question, believing the evidence offered in favour of "spontaneous generation" to be thus vitiated, cannot accept it. They know full well that the chemist now prepares from inorganic matter a vast array of substances, which were some time ago regarded as the sole products of vitality. They are intimately acquainted with the structural power of matter, as evidenced in the phenomena of crystallization. They can justify scientifically their *belief* in its potency, under the proper conditions, to produce organisms. But in reply to your question, they will frankly admit their inability to point to any satisfactory experimental proof

that life can be developed, save from demonstrable antecedent life.'[1]

What is the justification for this *belief* that non-living matter can, under proper conditions, produce organisms?

There is a substance called *acetylene*, the molecule of which is made of two atoms of carbon, holding together by two hooks from each, and four atoms of hydrogen each holding on by its one hook to a carbon atom. It is made by driving hydrogen between the tremendously hot carbon points of an electric light; directly, therefore, from the elements. If we make acetylene pass through a red-hot tube, we shall get what is called *benzene*. A molecule of benzene is a game of round-the-mulberry-tree played by six carbon atoms, each one holding by two hooks to its right-hand neighbour and one to its left, while it keeps the remaining hook for a hydrogen atom. It is therefore made of *three* molecules of acetylene, each of which has dropped two hydrogen atoms in order to join hands with the other two molecules. How does this molecule of benzene get made out of the three molecules of acetylene?

There are two answers. If anybody likes to assert that benzene can never be made out of acetylene without the presence of pre-existing benzene, it is impossible to disprove his statement. We should have no means of discovering the presence of two or three molecules of benzene vapour in the original hydrogen that we made the acetylene of. It is known that the first step is often a difficulty in the formation of chemical compounds, and that when the process has once begun, the new compound has the property of assisting the formation of its like. Nobody knows why this is.

[1] *Belfast Address.*

No chemist, however, will, as a matter of fact, make this supposition about benzene. It is generally held that the benzene molecule is formed by the collision of three acetylene molecules in favourable positions. This collision is a *coincidence*. Each molecule meets another molecule many millions of times in a second; but I am not aware that anybody has calculated the number of times it meets two other molecules at once. We must know a great deal more of the constitution of atoms before we can calculate what proportion of these triple collisions is favourable to the formation of a benzene molecule; but there can be no doubt that the coincidence takes place an enormous number of times per second in every cubic centimetre of the gas, because a perceptible quantity of benzene is obtained.

There is another substance which can be made out of six carbon atoms and six hydrogen atoms, by fastening them together in a different way. I forget the name of it, but it is an unstable and explosive substance, which breaks itself up on the slightest provocation. We do not find this mixed up with the benzene, although the coincidence which formed it may have occurred quite as often as that which formed benzene. It becomes extinct because it is not adapted to the conditions.

On the other hand, we do find some more complex compounds mixed up with the benzene. These may have been partly made by collision of benzene molecules with acetylene molecules: partly by *coincidences* of a more elaborate character, such as the collision of four or five acetylene molecules. These are all *stable*; that

is to say, they are suited to the conditions, and therefore they survive.

Observe, then, that in this very simple case of the formation of an organic body (in large quantities benzene is always prepared from coal-tar) it is produced by a coincidence, and preserved by natural selection.

If we take thirteen carbon atoms instead of six, and combine them only in the simplest ways, so as to form an open chain with branches, it has been calculated by Cayley that 799 compounds are possible. How many of these are stable at a given pressure and temperature, nobody knows. In a gaseous mixture of paraffins, the *coincidence* necessary to form each one of them may occur many thousand times a second. Only those can survive which are stable under the given conditions. Such natural selection determines, for example, the compound ethers which go to make up the flavour of a pear.

Now those persons who believe that living matter, such as protein, arises out of non-living matter in the sea, suppose that it is formed like all other chemical compounds. That is to say, it originates in a coincidence, and is preserved by natural selection. Only in this case the coincidence is of the most elaborate and complex character. I once saw an estimate of the number of carbon atoms in a molecule of albumen. I cannot now lay my hands on the book in which I found it, but there were three figures in it. I do not believe, on the strength of that estimate, that there are over a hundred carbon atoms in a molecule of albumen; because, from the nature of the substance, I cannot imagine any evidence on which it might be securely

founded. But there can be no doubt that all the forms of living matter are enormously complex in chemical constitution. Now there may, of course, be half-way houses, less complex forms out of which they may be built up, just as acetylene forms a half-way house to benzene. Still, the coincidence involved in the formation of a molecule so complex as to be called *living*, must be, so far as we can make out, a very elaborate coincidence. How often does it happen in a cubic mile of sea-water? Perhaps once a week; perhaps once in many centuries; perhaps also, many million times a day. From this living molecule to a speck of protoplasm visible in the microscope is a very far cry; involving, it may be, a thousand years or so of evolution. Possibly, however, the molecule has from the beginning that power which belongs to other chemical bodies, and certainly to itself when existing in sensible masses, of assisting the formation of its like. Once started, however, there it is; the spontaneous generation, believed in as a possibility by the evolutionist, has taken place.

Why then do the experiments all 'go against' spontaneous generation? What the experiments really prove is that the coincidence which would form a *Bacterium*—already a definite structure reproducing its like—does not occur in a test-tube during the periods yet observed. Such a coincidence is the nearest thing to a 'special creation' that can be distinctly conceived. The experiments have nothing whatever to say to the production of enormously simpler forms, in the vast range of the ocean, during the ages of the earth's existence.

Allowing that this makes the thing possible, does it give any reason for believing that it has actually taken

place? We might get a direct demonstration if we knew the constitution of protein, and could calculate the chances of the coincidence which would lead to its formation in the sea. But on the other hand we have an argument precisely like that which we used in the case of the descent of man. We know from physical reasons that the earth was once in a liquid state from excessive heat. Then there could have been no living matter upon it. Now there is. Consequently non-living matter has been turned into living matter *somehow*. We can only get out of spontaneous generation by the supposition made by Sir W. Thomson, in jest or earnest, that some piece of living matter came to the earth from outside, perhaps with a meteorite. I wish to treat all hypotheses with respect, and to have no preferences which are not entirely founded on reason; and yet, whenever I contemplate this

simpler protoplastic shape
Which came down in a fire-escape,

an internal monitor, of which I can give no rational account, invariably whispers 'Fiddlesticks!'

I think, however, that the nature of the evidence which makes spontaneous generation probable is such that we cannot teach it in schools except to very advanced pupils. And the same thing may be said of the doctrine of evolution as a whole, regarded as involving the nebular hypothesis.

'Those who hold (says Tyndall) the doctrine of evolution are by no means ignorant of the uncertainty of their data, and they only yield to it a provisional assent. They regard the nebular hypothesis as probable, and in the utter absence of any proof of the illegality of the

act, they prolong the method of nature from the present into the past. Here the observed uniformity of nature is their only guide. Having determined the elements of their curve in a world of observation and experiment, they prolong that curve into an antecedent world, and accept as probable the unbroken sequence of development from the nebula to the present time.'

When I was seven or eight years old, I came across an article in *Chambers' Journal* upon Plateau's experiments with rotating oil-drops, and their bearing on the nebular hypothesis. I was highly delighted with this, and made notes of it on the fly-leaves of a book of Bible stories. My notion was that creation was precisely a large Plateau's experiment. Now I am pretty sure that this unfortunate circumstance retarded my knowledge of the nebular hypothesis by some years, because it gave me an idea that I knew all about it already.

Besides the nebular hypothesis, there are other doctrines about the origin of the world which it seems undesirable to have taught to our children. One[1] is an account of a wet beginning of things, after which the waters were divided by a firm canopy of sky, and the dry land appeared underneath. Plants, and animals, and men, were successively formed by the word of a deity enthroned above the canopy. Another account is of a dry beginning of things, namely a garden, subsequently watered by a mist, in which there were no plants until a man was put there to till it. This man was made from the dust of the ground by a deity, who walked about on the earth, and had divine associates,

[1] See that admirable book, *The Bible for Young People* (Williams & Norgate, 1873).

jealous of the man for sharing their privilege of knowing good from evil, and fearful that he would gain that of immortality also. The deity had taken a rib out of the man, and made a woman of it.

I do not see that we should mind the teaching of these stories, so long as others are taught along with them, such as that of the Chaldee God Bel, who cut off his head, moistened the clay with his blood, and then made men out of it; or of the Gods of our own race, Odin, Vale, and Ve, who walked about the earth until they found two trees, one of which they made into a man, and the other into a woman; or of Deucalion and Pyrrha, who threw stones over their heads, which became men and women. As soon as ever they can understand them children may be taught the reasons why the first two stories are quite different from the others, and, though contradictory, both of them true; as, for example, the nature of the evidence which connects or disconnects the stories with Moses, and which proves that Moses could have known anything about the origin of the world. But we ought not, I think, to allow either of these stories to be taught to our children *as a known fact*. It will be better to prepare them that they may by-and-by understand the attitude of the lover of truth towards these problems.

'If you ask him whence is this "matter" . . . who or what divided it into molecules, and impressed upon them this necessity of running into organic forms, he has no answer. Science is mute in reply to such questions. But if the materialist is confounded, and science is rendered dumb, who else is prepared with an answer?

Let us lower our heads and acknowledge our ignorance, priest and philosopher, one and all.

'His (the scientific man's) refusal of the creative hypothesis is less an assertion of knowledge than a protest against the assumption of knowledge which must long, if not for ever, lie beyond us, and the claim to which is the source of perpetual confusion upon earth'[1]

I do not propose to discuss here those difficult questions which were raised by Häckel and Nägeli about the relation of body and mind; because I hope soon to have an opportunity of dealing with them separately. But in regard to the teaching in schools of abstract and general conclusions derived from this branch of science still so very imperfect, so much in the air, it seems to me that Virchow has spoken with the utmost practical wisdom. The basis of it, indeed, the one point of firm ground on which the structure of mind-and-body lore can be built, is fully suited for teaching, as Virchow himself has pointed out. The theory of the eye, slowly elaborated from Lionardo to Kepler, from Kepler to Helmholtz, and the doctrine of perception founded upon it, these supply a safe foundation for whatever more may come. But the Plastidule-soul can take no harm by waiting awhile, until we are a little more clear about what we mean by it.

And this same judgment applies necessarily to another abstract and general conclusion from an unproved doctrine about body and mind; the conclusion that a man's consciousness survives the decay of his body. Such a conclusion can be at best, in the present state of knowledge, a hope, a conjecture, an aspiration;

[1] Tyndall, *Fragments*, pp. 421, 548.

it can have no claim to be regarded as a known fact. Those who hold to it may think it highly probable, they may strongly desire that it should be true, they may eagerly expect that better evidence will shortly be forthcoming; but they cannot be justified in teaching it to little children as a known fact. Of such a doctrine, surely, if of any doctrine, we ought to say: 'Do not take this for established truth; be prepared to find that it is otherwise; only for the moment we are of opinion that *it may possibly be so*.'

And in this case the reasons for such caution are deeper and stronger than the merely intellectual ones, because of the vast hold of this doctrine upon the hearts, and its serious influence upon the actions, of men. You, who teach it to your children, do so from the highest of motives, because you believe that it will influence their character for good, and strengthen them in the course of right conduct. But there are two things which you should carefully consider. The first is, that by teaching the doctrine too early you weaken its effect, because you teach it while it can be only half realized, and so prevent it from being realized afterwards. Dr. Martineau testifies to the greater power of a belief in immortality gained by the believer for himself, and strengthening a moral sense which has been formed on a different basis. Teach your children to do good and to eschew evil; if in later life they can find hope of an eternity of such action, it will make them happier and may make them better. But the experience of centuries condemns the practice of teaching the doctrine to little children, so as to make it familiar as an ill-understood conception, to weaken the power it might have for

good, and to help the perversion of it to superstitious uses.

The second point to be considered is the frightful loss and disappointment you prepare for your child if, as is most probable in these days, he becomes convinced that the doctrine is founded on insufficient evidence. It is not merely that you have brought him up as a prince, to find himself a pauper at eighteen. He may have allowed this doctrine to get inextricably intertwined with his feelings of right and wrong. Then the overthrow of one will, at least for a time, endanger the other. You leave him the sad task of gathering together the wrecks of a life broken by disappointment, and wondering whether honour itself is left to him among them. Leave him free of this doctrine, and his conscience will rest upon its true base, safe against all storms; for it is built upon a rock. Then he can never reproach you with raising hopes in him which knowledge is fated to blast, and with them, it may be, to blast the promise of his life.

THE END.

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