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EMPIRICISM VERSUS SCIENCE.

THERE is among the general public a perennial tendency to exalt and honour the man of affairs—the man whose business it is to pose as figurehead and carry through great schemes in the face of the community—at the expense of the quiet student or the scientific pioneer. And every now and then this permanent tendency is played upon by someone who ought to know better, and excited into more conspicuous vitality; sometimes taking the form of a demonstration in favour of “practice” as opposed to “theory,” sometimes the form of a flow of ribaldry against scientific methods and results. Such a periodical outburst seems to have broken loose just now, and the technical press is full of scoffs at men of science, and glorification of the principle of rule-of-thumb.

It is easy for students of science to smile at the absurdities thus propounded and to take no further notice. It is only statements which have a germ of truth about them that are able really to bite and sting. And if a feeling of momentary irritation is excited by reading some piece of extra absurdity set forth for the unedification and misleading of the public, the best antidote is a return to one's own work, and silence.

It is possible, however, sometimes to carry complaisance too far. “If you make yourself a sheep,” was one of Franklin's mottoes, “the wolves will eat you”; and there is sound worldly wisdom in the maxim, though it may be difficult always to reconcile it with some other precepts of a higher authority.

The only really irritating thing about these attacks is that they do not call things by their right names: if they did, the absurdity would be too glaring for anyone of importance to be taken in. So they sing the praises of empiricism and decry science under the totally false and misleading names of “practice” and “theory” respectively. Now plainly there is no real antithesis possible between theory and practice unless one is right and the other wrong or incomplete. If both are right, they must agree. If one is conspicuously right and the other conspicuously wrong, it is a very cheap and simple matter to distribute praise and blame.

Whenever there is discordance between theory and practice—a theory which says how a thing ought to be done, and the practice by which its doing has hitherto been attempted—manifestly there is something wrong with one or other of them. The blame should be applied to the error, and the error may lie equally well on either side. The practice in early steam-engines was to cool the cylinder at every stroke in order to condense the steam. It certainly did condense the steam, and was therefore successful. The self-styled “practical man” of that day would most likely have derided any small-scale laboratory experiments as futile and ridiculous, and not corresponding to the conditions of actual work. Nevertheless, that eminent theorist, James Watt, by studying the behaviour of saturated steam under various circumstances in a scientific manner, and by discovering that the pressure in any connected system of vessels containing vapour would rapidly become equal to the vapour-tension corresponding

to the coldest, did succeed in introducing a noteworthy improvement into a time-honoured practice. Again, the question of the specific heat of saturated steam, whether it be zero, or positive, or negative, is a highly scientific question, first solved on the side of theory by Clausius, an eminent example of the purely scientific worker; but the fact that it is negative has an immediate practical bearing on the important subject of steam-jacketing, and fully explains the advantage of that process.

But it may be said the advantage of the steam-jacket was discovered by experience. Very likely. It is a conspicuous and satisfactory fact that progress can be made in two distinct ways. Sometimes the improvement is discovered by what may be termed blindfold experience: a certain operation turns out to be uniformly successful, and, without any further knowledge, that is sufficient justification of its performance. The observed fact that inhalations of chloroform produced temporary anæsthesia was sufficient justification of its use in surgery without any theory as to why it so acted. The motion of the planets in ellipses, according to certain laws, might have been deduced from the theory of gravitation; but historically those motions were deduced by a laborious comparison of observations. Sometimes observation is ahead of theory; sometimes theory is ahead of observation. It is mere nonsense to decry either on that account.

It is also absurd to deny that our knowledge of a fact, and our confidence in its use, and of all the conditions under which it may be used or may not be used, are enormously enhanced when one knows not only the bare fact by observation empirically, but when also one thoroughly understands the reasons and the laws connected with it. It would be justifiable to employ a successful drug even if one knew nothing of its mode of action, and could give no reason for its effects; but it is far more satisfactory to understand it exactly, and to have a complete theory of its physiological action. One can then decide beforehand, without empiricism, or a possibly fatal experiment, under what circumstances and to what constitutions it would be noxious.

The fact that lightning-conductors are often successful is ample justification for their use, but it will be far more satisfactory when, by help of laboratory experiments and theory, one understands all the laws of great electrical discharges, and can provide with security against their vagaries.

These things are truisms, but it would seem to be sometimes necessary to utter truisms.

Sometimes one hears a judgment such as this: “Yes, he is a very good man in some ways, but he is too much of a theorist.” And then there is a sapient shaking of heads, as if the term “theorist” were an intelligible term of abuse. You suppose it means that the wretched man knows too much about the mode of working of things; too much about the strength of materials, too much about graphical statics, if he is engaged in building a bridge; but if you ask the meaning of the fatal term, you find it explained in some such way as that “he does not attend to details,” or “he does not look after his workmen,” or “he accepts rotten materials.” Then why not apply some term which shall legitimately mean these things, such as careless, or lazy, or ignorant, or unbusiness-like? Probably the word “theorist” as a term

of abuse is meant to euphemistically imply all these things. If so, it is a foolish euphemism.

There are certain notable theorists who are so eminent that no one is willing to stultify himself by abusing them; and inasmuch as the superabundant energy of some of these men often leads them occasionally out of their main pursuits into alien fields of activity, wherein nevertheless they frequently shine as the equals or superiors of smaller men whose life-work lies in the same fields, it is becoming customary to ingeniously attempt to exclude them from the class it is wished to denounce, and to include them in the circle wherein they are comparatively amateurs or dabblers.

At the recent meeting of the British Association the old joke was repeated about claiming Sir William Thomson as an electrical engineer instead of a physicist and mathematician. This is all very well as a joke, but the British public is too apt to take these things in sober earnest. The range of activity of a pre-eminently great man is frequently not a narrow one, and he is extremely likely to shine in whatever he takes up, even if it be only as a pastime, or as relief from more serious work. Sir Isaac Newton made an excellent Master of the Mint. Perhaps therefore, in his day, City men claimed him as essentially one of themselves. Sir William Thomson has amused himself with navigation, as well as with electrical engineering.

This outcry against theory is becoming absurd. It used to be confined to the conclusions of mathematics. It is indeed still rampant there, but it is being extended also to conclusions deduced in the laboratory. Everything done in the laboratory or the study is looked at with suspicion. The right place to study the laws of steam-engines is on a locomotive. The right place to study marine engineering is in the hold of a steamship. The only place to study lightning is in a thunderstorm.

Give out these plausible fallacies with a certain unction to a British audience, and you will evoke "loud applause." It is so easy to evoke loud applause by talking pernicious but plausible nonsense. Your British audience hates to think, and likes to have its stupidity tickled by some after-dinner sentiment, which makes it feel that, after all, no one really knows anything about anything; that whoever professes to understand a subject theoretically is *ipso facto* a quack; and that the only difference between itself and everybody else is that some people cloak their ignorance under a show of learning and mathematical formulæ. These humbugging theorists may therefore be cheaply derided. "There is a lot of arrant humbug stowed away now and then under a mathematical cloak," said a technical paper the other day.

And what of the "practical" man? Any man who talks sense and goes to the bottom of things, so as to really understand and to be able to explain what he means and how things are, is essentially a practical man. One class has no right to monopolize this adjective. A mathematician may make statements according completely with facts and phenomena, and leading to the most complete understanding of every-day truths. An empiric may utter the most glaring absurdities, utterly out of harmony with anything in heaven or earth, or under the earth. Is Prof. Stokes therefore to be styled unpractical, and Prof. (shall we say) Pepper practical?

Push the matter to an extreme, and you can enunciate sentences like these. If you want to know about steam-engines and compound locomotives, you must go, not to theorists like Rankine, or Unwin, or Cotterill, or even to Mr. Webb. The driver of the Scotch express is the man really able to give you trustworthy and practical information.

If you want to know the principles underlying the construction of ships, and why some ships go quicker than others, do not think of applying to the writings of the late William Froude with his nonsensical paraffin toys, but consult the captain of the *Umbria* or the *City of Rome*.

We have set down these sentences as a *reductio ad absurdum* of some of the claims set forth in favour of empiricism as against science, under the specious and plausible heading of practice against theory: but really they are not a whit more absurd than much that is seriously argued; and were they propounded under favourable auspices to an average British audience, they would very likely be swallowed without nausea. The experiment is almost worth trying, only it would be difficult for anyone himself faithless to avoid some suspicion of irony, which would be fatal to success.

Space may be afforded for a few more very brief extracts from some of the engineering and technical journals during the past month. The first is so choice as to need no comment:—"The world owes next to nothing to the man of pure science. . . . The engineer, and the engineer alone, is the great civilizer. The man of science follows in his train." This doctrine is explained and illustrated by insistence on the utility of Faraday's work in connection with magneto-electricity, until taken up and realized by the practical man.

In the same paper, a week later, occurs the following:—"No one knows anything with certainty about lightning outside of the common knowledge possessed by most fairly educated people." And again, "We fail to see that what is true in the laboratory must be true out of doors."

This is interesting as an almost exact reproduction of one of the historic objections made to Galileo's unwelcome discovery of Jupiter's satellites. It was then similarly maintained that, though the telescope was all very well for terrestrial objects, it was quite misleading when applied to the heavens.

An instance of a converse proposition is told in a recent popular work on astronomy (is it Sir R. Ball's?), about a farmer and amateur astronomer, who came to the writer with a revolutionary system of astronomy, based upon a number of observations which he had taken with a sextant of the altitude of the heavenly bodies. The gentleman had thus found that the generally received opinion about the distances of the fixed stars was extremely erroneous. But on inquiry it turned out that his altitudes were all calculated on the common-sense and well-known fact that sixty-nine miles make a degree. Finding it impossible to get the gentleman to put his mind into an attitude for receiving any instruction on the theoretical subject of the measurement of angles, the representative of the orthodox clique who impose their statements on the world as something more trustworthy than common information prevailed on the gentleman to apply his sextant to determine the altitude of his own barn. This *reductio ad absurdum* was avoided, however, and the overthrow of orthodox

astronomy successfully maintained, by the hoped-for convert "failing to see that an astronomical instrument had any application whatever to terrestrial objects."

A paragraph recently inserted in an electro-technical journal, with editorial sanction, styles mathematicians "the accountants of science," and goes on in a tone less comic than bitter:—"When some young shaver shoots off his school learning" (*i.e.* uses some mathematical operation or notation), "I feel inclined to reply to him in Italian, as both are as generally and completely understood in the Society of —." Now if the subject under discussion were, say, passages in Tasso or Dante, an Italian quotation would be very natural, and persons ignorant of the language would hardly be invited, or indeed anxious, to express an opinion. Is it not equally clear that when the subject-matter is numerical magnitude and quantity, the appropriate language may sometimes have to be used?

It has always been customary, as we have before remarked, for the empiric to feel some hostility to the mathematician, especially to the mathematician who endeavours to apply his powerful and beautiful machinery to the elucidation of the facts of Nature. But only recently has it become the fashion to extend the same attitude of mistrust and dislike to the experimental worker in a laboratory. Both these hostilities probably have their root in an instinct of self-protection. Without them the empiric would be constantly suffering wounds in his self-esteem, and might lose confidence in his faith as to the universal prevalence of ignorance and the advantages of rule-of-thumb. For a man of the world professing a certain science to have to recognize a certain number of minds as immeasurably superior to his own, and their conclusions in that very science as being almost certainly correct, although flatly opposed to his own instinct and traditions: this is in many cases intolerable. He cannot away with these great theorists, neither can he in his heart condemn them; but he can do his best to deceive himself and others by extending to them euphemistic terms of abuse, and by pretending that he could do all that they do if only he thought it worth while. He may even go further, and flinging abroad a universal accusation of ignorance will easily delude a gullible public into the belief that knowledge is after all only a matter of opinion, and that what one man says is quite as good as what is said by another.

And in this procedure he is fairly secure against any retaliation from the great men. They are deeply and painfully conscious of ignorance in one sense: their knowledge sits lightly upon them; and when broadside and grotesque accusations of ignorance are hurled at them with the intention of putting them on a level with the uneducated and, in quite another sense, "ignorant" populace, they resent it not; scarcely recognizing, indeed, the absurdity of the position.

The hostility of the "practical man" for the systematic and recondite methods of science was at one time mainly borne by mathematicians, because they it was mainly who spoke a language and thought thoughts too high for common apprehension. Since then experiment has become more exact, more illuminated by theory, more scientific and less empirical; hence it is that the hostility is now being extended to the experimentalist in his laboratory as well.

But really, it may be rather offensively suggested, what other attitude can be taken up? If a man is to be capable of getting schemes through Parliament, of impressing a jury, and generally of playing to the gallery and becoming a power in the State, he cannot, unless very exceptionally endowed, have the aptitudes and powers proper to a man of high science. And yet it will never do to allow even to himself that the scientific man is in his own line immeasurably above him. Such a reverent and submissive attitude would ruin his chance with the gallery at once. Swagger and a confident front are more than the tricks of the trade, they are the essentials to success.

We are glad to recognize, however, that the recent outburst against the methods and conclusions of pure science is the work of the camp-followers rather than of the leaders on the commercial side. There have been and are several conspicuous examples not only of the scientific man taking a high position on the commercial side, but also of the commercial man taking a high position in the ranks of pure science. This interchange of individuals, and the further *rapprochement* which the great extension of science into industrial life of various kinds has caused, and must in the future still further cause, are making it now clearly recognized how intimately pure science and the commercial applications of science are connected together, how great is their mutual dependence on each other, and how essential to the well-being of each is a close and friendly co-operation with the other.

These facts, and the friendly attitude of the leaders on both sides, render the attempt made in the rank and file to sow discord between the two great classes the more absurd, and must make it in the long run entirely futile.

THE MESOZOIC MAMMALIA.

The Structure and Classification of the Mesozoic Mammalia. By H. F. Osborn. *Journ. Ac. Nat. Sci. Philadelphia*, Vol. IX. No. 2. (Philadelphia: Published by the Academy, 1888.)

IN the elaborate memoir before us, comprising eighty quarto pages of text, illustrated by thirty woodcuts and two plates, Prof. Osborn, of Princeton College, New Jersey, gives us the result of his researches into the structure of the Mesozoic and allied Tertiary Mammals, based upon observations carried on both in America and Europe. As a rule, these Mammals are of small size, and are mainly known to us by more or less imperfect jaws and teeth; by far the greater number of specimens consisting of the lower jaw or mandible. Now, it is well known that even in groups of the smaller Mammals which are well represented at the present day, such as the Shrews among the Insectivora, or the Bats, it is almost, if not quite, impossible to recognize many of the genera, to say nothing of the species, when we have to deal only with a series of fossil or sub-fossil lower jaws from the cavern or later Tertiary deposits. And if this be so in groups with which we are well acquainted, the difficulty is of course increased many times over when we have to deal with forms having no close analogues among the existing fauna. The puzzle is further increased by the difficulty of referring such portions of upper jaws as are more rarely found to the species indicated by mandibles;