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SCIENTIFIC WORTHIES

V.—GEORGE GABRIEL STOKES

A GREAT experimental philosopher, of the age just past, is reported to have said, "Show me the scientific man who never made a mistake, and I will show you one who never made a discovery." The implied inference is all but universally correct, but now and then there occur splendid exceptions (such as are commonly said to be requisite to prove a rule), and among these there has been none more notable than the present holder of Newton's chair in Cambridge, George Gabriel Stokes, Secretary of the Royal Society.

To us, who were mere undergraduates when he was elected to the Lucasian Professorship, but who had with mysterious awe speculated on the relative merits of the men of European fame whom we expected to find competing for so high an honour, the election of a young and (to *us*) unknown candidate was a very startling phenomenon. But we were still more startled, a few months afterwards, when the new professor gave public notice that he considered it part of the duties of his office to assist any member of the University in difficulties he might encounter in his mathematical studies. Here was, we thought (in the language which Scott puts into the mouth of Richard Cœur de Lion), "a single knight, fighting against the whole *mêlée* of the tournament." But we soon discovered our mistake, and felt that the undertaking was the effect of an earnest sense of duty on the conscience of a singularly modest, but exceptionally able, and learned man. And, as our own knowledge gradually increased, and we became able to understand his numerous original investigations, we saw more and more clearly that the electors had indeed consulted the best interests of the University; and that the proffer of assistance was something whose benefits were as certain to be tangible and real as any that mere human power and knowledge could guarantee.

And so it has proved. Prof. Stokes may justly be looked upon as in a sense one of the intellectual parents of the present splendid school of Natural Philosophers whom Cambridge has nurtured—the school which numbers in its ranks Sir William Thomson and Prof. Clerk-Maxwell.

All of these, and Stokes also, undoubtedly owe much (more perhaps than they can tell) to the late William Hopkins. He was, indeed, one whose memory will ever be cherished with filial affection by all who were fortunate enough to be his pupils.

But when they were able, as it were, to walk without assistance, they all (more or less wittingly) took Stokes as a model. And the model could not but be a good one: it is all but that of Newton himself. Newton's wonderful combination of mathematical power with experimental skill, without which the Natural Philosopher is but a fragment of what he should be, lives again in his successor. Stokes has attacked many questions of the gravest order of difficulty in pure mathematics, and has carried out delicate and complex experimental researches of the highest originality, alike with splendid success. But several of his greatest triumphs have been won in fields where progress demands that these distinct and rarely associated powers be brought simultaneously into action. For there the mathematician has not merely to save the experimenter from the fruitless labour of pushing his inquiries in directions where he can be sure that (by the processes employed) nothing new is to be learned; he has also to guide him to the exact place at which new knowledge is felt to be both necessary and attainable. It is on this account that few men have ever had so small a percentage of *barren* work, whether mathematical or experimental, as Stokes.

Like that of the majority of true scientific men, his life has been comparatively uneventful. The honours he has won have been many, but they have never been allowed to disturb the patient labour in which short-sighted Britain has permitted (virtually forced) him to waste much of his energies. He was born on August 13, 1819, at Skreen, Co. Sligo, of which parish his father was rector. At the age of 13 years he was sent to Dublin, where he was educated at the school of the Rev. R. H. Wahl, D.D. In 1835 he was removed to Bristol College, of which Dr. Jerrard was principal. He entered Pembroke College, Cambridge, in 1837; graduated in 1841 as Senior Wrangler and First Smith's Prizeman; became Fellow of his College in the same year; and in 1849 was elected Lucasian Professor of Mathematics. In 1857 he vacated his fellowship by marriage, but a few years ago was reinstated under the new statutes of his college. Stokes was elected Fellow of the Royal Society in 1851, was awarded the Rumford Medal in 1852, and was elected Secretary of the Society in 1854.

A really great discoverer in mathematics or physics does not seek the readily-accorded plaudits of the ignorant masses or of the would-be learned rich. He knows the worthlessness of such verdicts (in any but a possible pecuniary sense); his joy is in the conviction that, within a very short time after their publication, his discoveries will be known to all who are really capable of comprehending them; that his experiments will be repeated, and in many cases even extended, by some of them before he has made further advance. He is a true soldier of science, and fights for her cause, not for his own hand; he joys quite as much in an advance made by another as in his own. When the army has passed on from the well-fought field, let the camp-followers deck themselves with frippery from the spoil, and talk pompously of the labours of the campaign! Them the many-headed will applaud, too often even sage rulers will lavishly reward them. The true votary of science, in this country at least, rarely meets with State encouragement and support. Mole-eyed State! Men whose undisturbed leisure would be of incalculable value, not only to the instruction but to the material progress of the nation, have to devote the greater part of their priceless intellects and time to work like common hodmen for their children's bread! It is the long-consecrated, and still common, custom of our mighty empire to harness Pegasus to the dust-cart! Ignorance alone is to blame for this, ignorance that cannot distinguish Pegasus from a jackass!

Perhaps the simile may be thought exaggerated. But what a comment on things as they are is furnished by the spectacle of genius like that of Stokes' wasted on the

drudgery of Secretary to the Commissioners for the University of Cambridge; or of a Lecturer in the School of Mines; or the exhausting labour and totally inadequate remuneration of a Secretary to the Royal Society! Men know about these things, as well as about a good many other important things, much better in Germany than we yet know them; and it will not be very long before we in our turn will be forced to know them to the full as well. Let us hope that this knowledge may come to us in a more gentle form than that of the rude and sudden lessons which have so lately been read (for something very like the same fatal blindness) alike to Austria and to France!

The magnificent Royal Society *Catalogue of Scientific Papers*, one of the greatest boons ever conferred on men of science, shows that up to 1864 Stokes had published the results of some *seventy* distinct investigations; on an average between three and four per annum. Several of these are controversial; designed not so much to establish new results as to upset false and dangerously misleading assertions. Some are improvements on the mathematical methods usually employed in the treatment of comparatively elementary portions of physics; and, especially those on the *Hydrokinetic Equations* and on *Waves*, are exceedingly valuable. These appeared in the *Cambridge and Dublin Mathematical Journal*.

Of the higher purely mathematical papers of Stokes we cannot here attempt to give even a meagre sketch. It would be hopeless to attempt to give the general reader an idea of what is meant by the "Critical Values of the Sums of Periodic Series," or even by the "Numerical Calculation of Definite Integrals and Infinite Series;" though we may simply state that under these heads are included some of the most important improvements which pure mathematics have recently received with the view of fitting them for physical applications.

In applied mathematics it is hard to make a selection, so numerous and so important are Stokes' papers. But we may mention specially the following:—

"On the Friction of Fluids in Motion, and the Equilibrium and Motion of Elastic Solids." *Camb. Phil. Trans.*, 1845.

"On the Effects of the Internal Friction of Fluids on the Motion of Pendulums." *Ibid.* 1850.

(In these papers, for the first time, it is shown how to take account of difference of pressure in different directions in the equations of motion of a viscous fluid; the suspension of globules of water in the air as a cloud is for the first time explained and the vesicular theory utterly exploded; and the notion of Navier and Poisson as to a necessary numerical relation between the rigidity and the compressibility of a solid is shown to be untenable. Each one of these is a distinct, and exceedingly great, advance in science; but they are only single gems chosen, as we happen to recollect them, from a rich treasury.)

Then we have a series of magnificent researches on the "Undulatory Theory of Light," for the most part also published in the *Cambridge Philosophical Transactions*. Of these we need mention only three:—

"On the Dynamical Theory of Diffraction." 1849.

(Here, in addition to a splendid experimental inquiry as to the position of the plane of polarisation with reference to the direction of vibration, we have an invaluable inquiry into the properties and relations of Laplace's Operator, an inquiry bearing not alone upon the Undulatory Theory, but also upon gravity, electric and magnetic attractions, and generally upon all forces whose intensity is inversely as the square of the distance.)

"On the Colours of Thick Plates." 1851.

"On the Formation of the Central Spot of Newton's Rings beyond the Critical Angle." 1848.

As another most important contribution to the undulatory theory we have his

"Report on Double Refraction." *British Association Report*, 1862.

Then we have a full investigation, in one respect carried to a third approximation, of the propagation of waves in water; a complete explanation of the extremely rapid subsidence of ripples by fluid friction, &c.

Another paper of great value is—

"On the Variation of Gravity at the Surface of the Earth." *Camb. Phil. Trans.*, 1849.

Perhaps Stokes is popularly best known by his experimental explanation of *Fluorescence*. This is contained in his paper

"On the Change of the Refrangibility of Light." *Phil. Trans.*, 1852.

There can be no doubt, as was well shown by Sir W. Thomson in his Presidential Address to the British Association at Edinburgh in 1871, that Stokes (at least as early as 1852) had fully apprehended the physical basis of *Spectrum Analysis*, and had pointed out *how* it should be applied to the detection of the constituents of the atmospheres of the sun and stars. Since 1852 Thomson has constantly given this as a part of his annual course of Natural Philosophy in the University of Glasgow; but, till 1859, under the impression that it was quite well known to scientific men. Balfour Stewart's experiments and reasoning date from 1858 only, and those of Kirchhoff from 1859.

In some of Stokes' earlier hydrokinetic papers, he for the first time laid down the essential distinction between rotational, and differentially irrotational, motion, which forms the basis of Helmholtz's magnificent investigations about vortex-motion.

Another most valuable paper (a short abstract of which, in the *Reports of the British Association for* 1857, seems to be all that has been published) completely clears up the difficulties which had been felt with regard to the very curious effects of wind upon sound, and the diffraction of waves in air. The singular fact noticed by Sir John Leslie that the intensity of a sound depends, *ceteris paribus*, to a marked extent upon the nature of the gas in which it is produced, is explained in an admirable manner by Stokes in the *Philosophical Transactions* for 1868 in a paper entitled "On the Communication of Vibration from a Vibrating Body to the surrounding Gas."

Of late years Stokes has not published so many papers as formerly: one reason at least has been already hinted to the reader. But there is another. It is quite well known that he has *in retentis* several optical and other papers of the very highest order, but cannot bear to bring them out in an incomplete or hurried form. No doubt he may occasionally hint at their contents in his lectures, but his (undergraduate) audience are likely to take them for well-known and recognised facts [as Thomson unfortunately did in the case of Spectrum Analysis], and so

they run the risk of being wholly lost—unless independently discovered. But he has not time to draw them up with the last possible improvements, nor to publish that Treatise on Light and Sound which we all so eagerly expect. Hence the world has to wait while the author devotes his powers to work which a clerk could do nearly as well!

Of these later papers, however, that "On the Long Spectrum of the Electric Light," and particularly those on the "Absorption Spectrum of Blood," are of very great value, the latter especially for their physiological applications.

We must not omit to mention that, partly in conjunction with the late Mr. Vernon Harcourt, Stokes has made a most valuable experimental inquiry into what is called *Irrationality of Dispersion*, chiefly with a view to the further improvement of achromatic telescopes.

He has also proved, by very exact measurements, that the wave-surface for the extraordinary ray in uniaxal crystals is (at least to the degree of accuracy of his experiments) rigorously an ellipsoid of revolution. From the theoretical point of view this is a result of extreme importance; and it is a happy illustration of what we have already said as to the conjunction in Stokes of the experimenter and the mathematician.

Several of his papers are devoted to the extraordinary and, at least at first sight, apparently incongruous properties of the Luminiferous Ether—more especially with the view of explaining (on the Undulatory Theory) the observed Law of the Aberration of Light. He has also reaped an early harvest from the even now promising field of the connection between *Absorption* and quasi-metallic *Reflection* of Light—and has furnished the student with an admirably simple investigation of the *Conduction of Heat in Crystals*.

It is quite possible that, in hurriedly jotting down our impressions and recollections of Stokes' work, we may have omitted something of even greater value than we have recorded. But if so, does the fact not show the absolute necessity that exists for a reprint of all Stokes' works, collected alike from the almost inaccessible *Cambridge Philosophical Transactions*, the ponderous *Philosophical Transactions*, &c., no less than from the *Sitzungsberichte* of the Imperial Academy of Vienna, in which we find Stokes suggesting a preservative for miners against the deadly vapour of mercury?

Stokes was President of the British Association at the Exeter meeting in 1869. The Address he then delivered was a thoroughly excellent and appropriate one; and its modest but firm concluding paragraphs are well calculated to reassure those who may have been perplexed or puzzled by the quasi-scientific materialism of the present day.

P. G. TAIT

SCIENCE EDUCATION FROM BELOW

THE Science Department of the Committee of Council on Education was instituted twenty-two years ago. At that time the general public was far from being alive to its advantages, and for the first seven years it achieved very little. The second term of seven years showed a considerable increase in the number of science schools throughout the country; but it was only during the third septennial period (1867 to 1874) that the importance of such an educational agency became in any sense duly appreciated; and it is not too much to say that it is now one of the most important scientific organisations in this or any country.

Still, in the Government schools as elsewhere, science teaching hitherto has had uphill work, nor must we delude ourselves with the pleasing idea that the road is now all smooth and level. It is true that for some years past the extension of education in this direction has been a popular cry, and a good deal of political capital has been made of it. The international exhibitions have been mainly at the bottom of this; and one of the great benefits derived from those occasions of friendly rivalry has been the diminution of that self-satisfaction which is the greatest bar to progress. Economists have reminded us that we have been relying upon our physical advantages as a nation, rather than the intelligence of our people, in our competition with the rest of the world, and that if we are to maintain our supremacy we must not be behind other nations in the practical applications of knowledge. The argument goes home readily enough to a commercial people, but it is one thing to admit the fact, and another to apply the remedy. The majority of the upper class, from the circumstances of their position and education, are indifferent to the matter. It is foreign to the idea of our older Universities and public schools; and these have exercised, and still continue to exercise, a direct influence over the middle-class schools. True, the number of professional chairs is on the increase, and opportunities are now afforded of practical study in physical and chemical laboratories; but it cannot be pretended that these studies yet take their proper rank amongst the rest. The inferior educational establishments naturally take their cue from the superior ones; indeed, they do so almost as a matter of necessity. They have not only to please the public, but the masters can only impart to their scholars the knowledge they themselves possess; and until on the one hand it be required that the pupils should be taught science, and on the other the masters find it to be an indispensable portion of their educational course, the progress of these studies in private schools will be but slow. In our large towns special teachers can be had for the purpose, but as a fact they are discouraged, the subjects they teach being generally regarded as extras and reduced to a minimum so as not to interfere with the regular routine of the school and the work of the resident masters. So long as the time of the boys is to be wasted in making wretched Latin verses, and the amount of their learning is to be measured by the retentiveness of their memory rather than by how much they understand, the hope of progress in this quarter must inevitably be small.

The operations of the Government department have, however, no direct bearing upon any such schools, unless the principals choose to avail themselves of it as an examining body; but we believe the indirect influence to be already considerable, and likely to become more so in the course of the next few years. Nothing will tend to arouse the proprietors of our boarding schools throughout the land to the necessity of improving both the quantity and quality of the instruction given in them, more than the upward pressure that will be exerted by those who