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

in a social sense occupy the level immediately below them. The moving impulse is from below, and to that we must now more particularly direct our attention.

From the first the South Kensington establishment has acted as an examining body, and the staff appointed for that purpose includes the names of the most eminent professors in natural and physical science. Subject to certain limitations the passes carry with them pecuniary grants to the authorised local teachers; prizes and medals of honour to the most proficient of the students. The department also makes grants in aid of scholarships and the Royal and local exhibitions, as well as having the administration of those scholarships which were endowed by Sir Joseph Whitworth. Grants are also made in aid of new local schools of science, and towards the cost of the apparatus which they may require. Special classes for the improvement of acting teachers are held by some of the Professors. Lastly, we must not omit to mention in our summary the well-known museum under its management, and the too little known educational library which is available to the general public on payment of a very trifling fee.

The twenty-three branches of study dealt with include Mathematics, Mechanics, Physics, Natural Science, and some of the Applied Sciences. The six most popular among the students are Physical Geography; Pure Mathematics; Animal Physiology; Magnetism and Electricity; Inorganic Chemistry; Acoustics, Light, and Heat; some, such as Navigation and Nautical Astronomy, are, from their very nature, little studied except in special localities. The large preponderance of students in Physical Geography, generally nearly double that of the next in rank, is due to girls' schools, in which it forms a leading feature, being included.

Those who care for statistics will be interested in the following table, for which we are indebted to the courtesy

—	I.—Practical Plane and Solid Geometry.	II.—Machine Construction and Drawing.	III.—Building Construction.	IV.—Naval Architecture.	V.—Mathematics. Stages 1, 2, 3.	V—Mathematics. Stages 4, 5.	V.—Mathematics. Stages 6, 7.	VI.—Theoretical Mechanics.	VII.—Applied Mechanics.	VIII.—Acoustics, Light, and Heat.	IX.—Magnetism and Electricity.	X.—Inorganic Chemistry.	XI.—Organic Chemistry.	XII.—Geology.	XIII.—Mineralogy.	XIV.—Animal Physiology.	XV.—Elementary Botany.	XVI. and XVII.—General Biology.	XVIII.—Principles of Mining.	XIX.—Metallurgy.	XX.—Navigation.	XXI.—Nautical Astronomy.	XXII.—Steam.	XXIII.—Physical Geography.
No. of Classes.	211	248	181	12	537	18	5	105	66	357	485	322	49	162	15	414	66	35	6	10	32	9	73	686
No. of Students.	4631	5201	2518	183	10502	251	23	2265	1238	8463	12515	8259	701	3183	307	9470	1914	547	110	110	537	236	1260	17720
Students examined.	2500	3968	1302	117	6228	121	21	1668	704	5473	9122	5264	286	2598	116	6623	1168	209	95	173	251	92	908	13312

of the Secretary of the Science and Art Department. The table shows the actual state of the Science Classes in Great Britain during the last session.

The students for whom this machinery is designed belong to what may be termed the Industrial Classes, including all those in receipt of weekly wages, small tradesmen whose income does not exceed 200*l.* per annum, the children of any of these, all attendants at Public Elementary Schools, together with the teachers and pupil teachers of such, and the students in the Training Colleges which receive grants from the Education Department. This list of course includes such as constitute our mechanics' institutes and co-operative societies, in the programmes of which science classes now form an important element. In these the practical advantages are of a most direct character; but we are disposed to ascribe a still higher value to the assistance rendered in the Training Colleges and to the acting and pupil teachers in the Public Elementary Schools. Hitherto one of the difficulties which the department has had to contend against has arisen from the unavoidable circumstance that so many of the local science teachers are themselves self-taught, and their deficiencies have often been only too apparent in the character of the examination papers given in by their pupils: time, however, will do much to cure this as these teachers drop into the background and are succeeded by those who have gone through a systematic training.

The next table will show the rapid extension of the operations of the department during the years 1867 to 1873 inclusive. It will be seen, on comparing the figures, that the relative number of those who now go up for examination is greater than formerly, and that the increase in the number of papers worked is still greater in proportion.

Year.	Number of Science Scholars.	Number who went up for Examination.	Number of Examination Papers worked by them.	Number of Papers passed.
1867	10,230	4,520	8,213	6,013
1868	15,010	7,092	13,112	8,649
1869	24,865	13,234	24,085	14,550
1870	34,283	16,515	34,413	18,690
1871	38,015	18,750	38,098	22,105
1872	36,783	19,568	39,383	27,806
1873	48,546	24,674	56,577	35,100

It is abundantly clear then that through the enlightened and vigorous action of the Science and Art Department, a large bulk of the population of our country has received and is receiving an elementary scientific education. The work which Sir Henry Cole began can no longer be sneered at nor overlooked; its value to this country is beginning to be widely recognised, and the man who laid its foundations so wisely and well deserves the highest gratitude of his countrymen. Let us remember that only a few years ago there was little science education in the higher classes, and absolutely none in the lower; whereas, scattered over Great Britain, there are in active work this year no less than 1,707 certificated science teachers engaged in 1,374 science schools, teaching 4,104 separate classes, and the number of individuals actually receiving science instruction by this means reaches the enormous total of 48,274.

The Department, however, has not been content to rest on its laurels. Within the last few years it has undertaken a new work, which promises to be of the highest value. It was felt that the system of examinations needed supplementing. Teachers could gain certificates, and thus receive payment upon the results of their teaching, without any evidence of their having more than book knowledge. And it was found, indeed, that the great body of certificated teachers had, with few exceptions, little practical knowledge of the various subjects they taught. They could accurately describe an electrophorus, but they could not make one, nor use it perhaps when made; they knew all about the circulation of the blood or the structure of the heart, but they had never seen the one nor dissected the other. For the most part they knew nature as words, not as living facts. The eminent men who conduct the examinations for the Department saw the danger that was arising. Prof. Huxley addressed the Government upon the subject, and urged a practical class in Physiology for a certain number of science teachers certificated in that subject. By taking fresh men each year it was hoped that a large amount of practical knowledge would be diffused and gradually make its way through the various science classes. The late Government promptly acceded to the wish thus expressed, and in 1869 two short practical courses of a week each were given, the one on Animal Physiology and the other on Light.

The importance of even such brief instruction was so manifest that it was decided to enlarge the original conception. The details of the scheme were, however, difficult and needed to be grappled with in earnest. The body of teachers was large and distributed over wide areas; they could not afford the time nor money to come to London for instruction, and even if they had the requisite knowledge their means were too slender to enable them to purchase the apparatus needed for the proper demonstration of their subject. To the administrative genius of Major Donelly, the present chief of the Science Staff at South Kensington, no less than to his untiring zeal in the cause of scientific education, the country is mainly indebted for the solution of this formidable difficulty. Announcements were made to all the certificated science teachers throughout the country that a month or six weeks' gratuitous course of daily practical instruction, in various branches of experimental science, would be held at the new Science Schools at South Kensington during the summer vacation. Those who wished for this instruction were to apply to the Department; if selected, their expenses to and from London would be paid, and thirty shillings a week given to each as a maintenance allowance whilst they remained in London. It was soon found impossible to accommodate all who applied; at present the applications are about three times as many as can be taken. In the selection of the men most needing this kind of instruction, and who would afterwards make the best use of it, arose another difficulty. But, as before, the excellent judgment of the Secretary of the Science and Art Department, and the careful scrutiny of his officers, led to a choice of such capital men that the wisdom of their mode of selection has been shown in the happiest manner.

At the present moment sixty teachers are working at Practical Chemistry under Prof. Frankland and Mr. Valentin; thirty-one teachers are studying Heat practically under Prof. Guthrie; these have been preceded by the same number who have worked at Light; twenty-one are studying Mechanics with Professors Goodeve and Shelley; twenty-eight are being taught Geometrical Drawing by Prof. Bradley; and thirty-eight are working at Machine Construction and Drawing under Prof. Unwin.

The applicants give a list of the courses they wish to attend, in much the same way that one hands in a selected list of books to Mudie's Library; they are allotted courses as far as possible in their order of preference, and may, in successive years, take successive subjects. The courses only last from three to six weeks. Chemistry this year runs on from the 1st to the 23rd of July; Physics, from June 23rd to Aug. 3rd; Mechanics and Geometrical Drawing from June 30th to July 22nd; and Machine Construction from 27th July to 13th of August. It might be imagined that such short courses could be of little real use; experience has, however, shown the reverse. The fact is, the men in each subject are thirsting for information, they know they have now a chance which may never recur to them; in a few short weeks they must strive to win much knowledge, which they not only desire for its own sake, but which means bread and cheese to their families. They are prompted, therefore, by every inducement to make the best possible use of their time. It is this heartiness of work combined with the admirable system of instruction given by each professor that has made these short summer courses so remarkably effective.

Capital evidence of the value of what is being done may be had by simply walking through the different rooms of the Science Schools and observing the teachers at work. If, for example, we go into the Biological department,* we find every man busily dissecting plants or animals, each one seated at a separate little table, and each provided with an excellent microscope and proper instruments and suitable specimens. The earnestness of everybody in the room strikes one very forcibly; and as we look at the fresh specimens at every table, we think of the labour implied in choosing typical objects and securing forty or fifty of each daily. Professors and students unquestionably are hard at work. If we now go into the fine chemical laboratories a like impression is produced. Here are one set making perhaps their first

practical acquaintance with the reactions which they have so often written down, and which in future they will regard with an altogether new interest and delight. Others more advanced are conducting analyses, or perhaps making "combustions"—if in the advanced group, studying organic chemistry. All are intensely busy, and work with a fixed purpose before them. The same quiet activity is noticeable in the different subjects going on in the other rooms. Entering last the physical laboratory on the ground floor, we find the teachers constructing apparatus which, though simple and often rough, is well adapted for teaching purposes. The raw material is provided them, printed instructions are given to each one, and under the direction of Prof. Guthrie, and the gentlemen associated with him, the most useful physical instruments are built up. These instruments are then employed in repeating the experiments seen in the morning lecture, or in making physical measurements wherever it is possible to do so. The homely apparatus, it is true, has not the polish of the instrument-maker, but in delicacy and efficiency is, generally speaking, far better than the teachers could purchase out of the small grants allowed to them for that purpose. With a wise liberality the Department permits each teacher to take home with him, without any charge, all the apparatus he himself has made: and one can easily imagine the pleasure with which these simple and useful instruments are afterwards looked upon and used by those who have made them. Nor is this all; the impulse to sound and practical science teaching is given, and at the same time the hands have been disciplined to useful skill, and the senses trained to accurate observation. After such preparation good use is made by the teachers of the more refined physical instruments which are set before them, but which are beyond their time or power to construct for themselves. It is most instructive to watch one of these men as he makes his first essay, and to trace the growth of his education in manipulative skill and in practical knowledge of his subject. We propose in our next number to go more fully into detail in this matter, and to describe some of the simple physical apparatus made by the teachers.

But the good work done by the Department does not rest here. In addition to giving practical instruction to teachers in short summer courses, free admission to extended courses of lectures and practical instruction in Chemistry, Physics, Mechanics, and Biology at South Kensington was granted to a limited number of teachers and students who intended to become science teachers. The selected candidates received a travelling allowance, and a maintenance allowance of 25*s*. a week while in London. The courses in Chemistry and Biology commenced in October of last year and ended in the early spring, when the courses in Physics and Mechanics began, and these closed at the beginning of this summer. From ten to sixteen teachers in training attended these different classes, and worked daily from 10 to 5 at the subjects they had chosen, in the evening writing up their notes and memoranda. Botany was not included in the foregoing series, but it was not forgotten. In January last the Lords of the Committee of Council on Education gave directions for a practical course on this subject. The course was given by Prof. Thiselton Dyer, and commenced on the 4th of March last, extending over eight weeks. It was attended by twenty-three science teachers and persons intending to become science teachers; these received precisely the same advantages as the teachers in training in the other subjects.

The value of such courses as these can hardly be overestimated, and we trust that no niggardly policy will lead the Government to restrict the great and good work they have begun. We hope there is no cause for apprehension in the apparent neglect of Biology in the summer course given this year, and what seems to us a little diminution of the strength of the staff in another subject. The improvement in the quality of the education given by the science teachers is already making itself felt. The reports of the May examiners for recent years show that "while the general average has been maintained throughout, the instruction had in some subjects decidedly improved." But it will necessarily take a few years to lift up so large a constituency. Surely and slowly it is being done, and the masses of the country are gaining a sound elementary knowledge of science. Whilst the magnificent laboratories of the Universities of Oxford and Cambridge and Dublin are nearly empty, Owens College and the classes under the Department are crowded with active and earnest workers.

The several large educational societies of England have availed themselves for some years past of the benefits offered by the Science and Art Department, with the object of turning the students out of their Training Colleges as thoroughly fitted as possible for their future scholastic career; and the continuance of this system for the future is now further assured by the necessity of their being provided with Government certificates in science in order to secure employment under the London School Board, or indeed at any of the first-class Elementary Schools throughout the country.

An impartial view of the facts we have placed before our readers will show that what the Universities might have done from above, others are doing from beneath. Science, instead of forming the delightful pursuit of the leisure classes, and thence distilling downwards to the workers, is, on the contrary, first becoming an integral part of the education of the toilers of the country. England, in fact, is being scientifically educated from below.

* This refers to last year; the teachers' summer course on Biology has been omitted this session.

DARWIN ON CARNIVOROUS PLANTS

I.

Insectivorous Plants. By Charles Darwin, M.A., F.R.S., &c. With Illustrations. (London: J. Murray, 1875.)

TO have predicted, after the publication of Mr. Darwin's works on the Fertilisation of Orchids and the Movements and Habits of Climbing Plants, that the same writer would hereafter produce a still more valuable contribution to botanical literature, characterised to an even greater extent by laborious industry and critical powers of observation, and solving or suggesting yet more important physiological problems, would have seemed the height of rashness. And yet, had such a prediction been made, it would have been amply justified by the present