the same year he was appointed Fullerian Professor of Physiology at the Royal Institution, so that there was no relaxation in lecturing work during these years. Owen was President of the British Association at its meeting at Leeds in 1857. We also get a glimpse of him at Aberdeen in 1859 but can find no trace in these volumes of his presence at the Oxford or Cambridge meetings of 1860 and 1862; indeed, even when noticing the publication of the memoir on the Aye-Aye in 1863, no reference is made to the remarkable paper read at the Cambridge meeting on the characters of this mammal as a test of the Lamarckian and Darwinian hypotheses of the transmutation and origin of species, nor is there any allusion to the "two pitched battles about the origin of species at Oxford," nor to Charles Kingsley's well-meant little squib, published during the Cambridge meeting by Macmillan and Co., "On the great Hippocampus Question."

Mrs. Owen, after a married life of nearly forty years, died in May 1873. In 1875 Owen refers to his daily task work becoming tiresome, as well it might to a man past seventy, but several important memoirs were published by him between this year and 1885, and in 1881 he delivered a long address to the Biological Section of the British Association at York, on the new Natural History Museum; this was almost his last public address, and it was delivered with a force and power that reminded his hearers of his early days. On January 5, 1884, Owen was, on his retirement from the post of Superintendent of the British Museum, gazetted a K.C.B. He was present at a meeting of the Linnean Society, at Burlington House, in May 1888, "to receive a gold medal." The medal thus alluded to was one of two struck in commemoration of the centenary of the Linnean Society; one medal was to be given to a botanist, and one to a zoologist. The botanist on this occasion was Sir Joseph Dalton Hooker. Up to the close of 1889 he was occasionally seen at the Athenæum. Early in 1890 he had a slight paralytic seizure, from which he never entirely recovered. In his well-known library, when able to be out of bed, he would sometimes sit for hours looking out wistfully at the view over the park, and on the morning of December 16, 1892, the end quite peacefully came.

As to Owen's position as a writer on anatomical science, we have no occasion to enter, for what we conceive to be by far the most interesting portion of these two volumes is a criticism, in the true sense of this word, thereof so straightforward, searching, and honest as to leave nothing further to be desired. We should like to have transferred the greater part of this analysis by Prof. Huxley of the work done by Owen to our pages. He doubts "if in the long annals of anatomy more is to be placed to the credit of any single worker" than to Owen, and his is "work some of which occupies a unique position, if one considers, not merely its general high standard of excellence, but the way in which so many of the memoirs have opened up new regions of investigation."

As to the judgment passed on the speculative side of Owen's work, will not all now deplore that so much tireless industry, great capacity, and extensive learning were spent on themes profiting so little as the archetype of the vertebrate skeleton and the nature of limbs? Perhaps it may seem to some that Prof. Huxley has devoted too much space to Owen's speculative writings, but, as he says:

"Obvious as are the merits of Owen's anatomical and palæontological work to every expert, it is necessary to be an expert to discern them; and endless pages of analysis of his memoirs would not have made the general reader any wiser than he was at first. On the other hand, the nature of the broad problems of the 'Archetype' and of 'Parthenogenesis' may easily be stated in such a way as to be generally intelligible; while from Goethe to Zola, poets and novelists have made them interesting to the public. I have therefore permitted myself to dwell upon these topics at some length; but the reader must bear in mind that whatever view is taken of Sir Richard Owen's speculations on these subjects, his claims to a high place among those who have made great and permanently valuable contributions to knowledge remain unassailable."

Several interesting portraits of Owen, taken at different periods of his life, form part of the illustrations of these volumes. There are also sketches of the Gateway, Lancaster Castle, and of Sheen Lodge, in Richmond Park.

ELECTROMAGNETIC THEORY.

Electromagnetic Theory. By Oliver Heaviside, F.R.S. Vol. I. (London: The Electrician Printing and Publishing Company, Limited, 1893.)

THE basis of Mr. Heaviside's treatise is the interlinked magnetic and electric circuits. This is taken from Maxwell, but it is much more fully developed, and the analogy between the electric and magnetic circuits is followed out with great care, and is insisted upon at every turn. That you can have a conductor charged electrically, while you cannot have a single magnetic pole, destroys the perfection of the analogy but little. There is a more serious hiatus in the absence of the magnetic analogue to an electric conductor. Mr. Heaviside, however, completes the analogy by imagining such things as magnetic conductors and magnetic currents. The magnetic displacement and convection currents of course exist, but magnetic conduction current, with its corresponding magnetic conductivity, is a most useful notion. The ideas of the magnetic current must not be confused with the unscientific notions of magnetomotive force and magnetic resistance, which are supposed to bring electromagnetism within the intellectual reach of the benighted practical man. At first Mr. Heaviside uses the hypothetical magnetic current as a means of giving his readers a thorough grasp of the interlinked circuits, and of completing the analogy between them. Later, however, in dealing with submarine messages, he shows that magnetic conductivity outside the wires, which is easy to treat mathematically, would have the same effect on the messages as electric resistance in the cable itself, which would be more difficult.

As Mr. Heaviside's first volume has been already reviewed in the *Electrician* and *Philosophical Magazine* by Profs. Fitzgerald and Minchin, and as the work is so full and so suggestive that a review might be longer than the book, this notice will deal mainly with matters not already fully discussed, though of course there will be some overlapping.

It is almost needless to say that Mr. Heaviside does not believe in action at a distance, that he regards energy as being continuous in space, and as moving as matter, and that he treats ether as an entity, and not as a working hypothesis. By the way, in discussing ether, as to whether it is stationary or not, stationary is generally taken to mean relatively to the earth which is honoured with our existence, or at least with regard to the sun which is to give us light. But if motion is considered with reference to infinite distances, the chances are that the ether moves past us at a speed in comparison with which v is infinitesimal. Mr. Heaviside hopes that in the future the young will be trained up to believe in ether as a thing, and will therefore believe in it; but this would be a sort of religion rather than knowledge. No one doubts that electrical disturbances are propagated at a finite speed, and matter, with its inconvenient properties removed or altered, provides a convenient working hypothesis; but to talk of the inconceivable as existing, is using words to which no concepts belong. As most people agree with Mr. Heaviside on these matters, however, it may be as well to say no more in a review. Dealing with the medium, or rather its states, Mr. Heaviside gets rid of the potential treatment. To him induction and its change is of primary importance, and potential is a mere derivative of it. The idea of induction as the essential and potential as derived is less common with the academical than the practical electrician, who also uses the notion of lines of induction.

This treatise is remarkable, among other things, in beginning almost at once with the propagation of disturbances at the speed of light. The author hopes that text-books on light will soon discuss electricity at the beginning instead of at the end. He certainly sets a good example by beginning a book on electromagnetism with the propagation of disturbances in time. By the way, he regards chemistry as an unmathematical science; it is to be hoped chemistry books will soon begin with thermodynamics and electricity, so as to lay an engineering foundation for the study of chemical action.

Mr. Heaviside is, as is well known, a determined opponent of the use of quaternions in physics, and an equally strong advocate of the use of vectors; and a long chapter is devoted to the "Elements of Vectorial Analysis," taking more than a third of the book. In quaternions, vector products have a part at right angles to both the vectors; the ideas thus fitted electromagnetism, and Maxwell availed himself of the conveniences of quaternion notation, and, to some extent, of quaternion ideas. The relations between vectors in quaternions are purely conventional, while in electricity they are physical in one sense, though in another they may be due to conventionalities of definition. The idea of the direction of a current flowing along in a wire was derived from the flow of water in a pipe, and it is possible that we might have so defined electrical and magnetic quantities, and so thought of them, that nothing corresponding to vector products or quotients came in when passing from one to the other of the electric and magnetic systems. Mr. Heaviside objects altogether to quaternions in physics, but does not differentiate clearly between vector and quaternion analysis, and professes that he does not or cannot understand quaternions. It is not likely he cannot. Perhaps he won't. One difficulty, in the way of students at least, is due to writers on quaternions defining something that is not adding as addition, and something that is not multiplying as multiplication, and to their removing the operand and treating the operator as a quantity. This leads to $S\alpha\beta$ being negative, to the square of a vector being negative, and to the reciprocal of a vector being taken in the opposite direction. When an eminent scientific writer recently found, by dividing the value of dy/dx by y that d/dx was equal to 628, some wrongly thought he did not understand the principles of the calculus; but he was only doing in figures what is done in letters in many branches of mathematics. Mr. Heaviside starts off with a definition of the "product" of two vectors. The scalar part is positive, and the vector part is as in quaternions, but there is no idea of the multiplier rotating the multiplicand, though he gives no reason why the multiplicand need not be looked upon as turned through a right angle. It may be asked how Mr. Heaviside avoids quaternions. Using the word in one of its many senses as the operator necessary to change a vector into another, he avoids the difficulty, for the present, by not dividing. Surely if vectors are to be multiplied they must also be divided. If we have the induction and current at an angle, we can find the force; is it not as reasonable to find the induction or current if the force and one of them is given? Perhaps Mr. Heaviside may devise a new quotient or operator which will do this. If $\alpha\beta = \gamma$ we might expect that $\gamma/\beta = \alpha$. This is not so in quaternions, because the scalar part of $\alpha\beta$ is lost, and the quaternion γ/β gives no scalar part. To recover α there might be a term $S\alpha\beta/\beta$. Perhaps Mr. Heaviside will give his own ideas about division in his next volume. Meanwhile, though he avoids the ideas of turning, every vector multiplier is just as much a quaternion as any in Hamilton or Tait, as far as the versor is concerned. A quaternion, though sometimes called an operator, is really two operators. Mr. Heaviside admits quaternions can be developed from his definitions. He also finds it difficult to think of energy disappearing in one place and appearing elsewhere without passing through intermediate space; surely then he can look upon a vector disappearing and reappearing in a new direction, and of a new length, as having passed through intermediate positions and lengths. He then gets the idea of roots of quaternions, $\sqrt{-1}$, and so on, without complicating vector analysis, and has a system which will do all his vector algebra well, which makes sense of imaginaries and exponential values of sines and cosines, which does not involve the study of new symbols or ideas, and which is already worked out: in short, quaternions. He finds difficulty in knowing when a vector is a vector, and when a quaternion. The answer is: it is a vector when it is a quantity, and the versor of a quaternion when it is an operator. There would be no difficulty if people did not confuse an operator with the quantity that specifies it. Confusion, which is common to Mr. Heaviside's vector algebra, may come in between the scalar and vector part of the product of two vectors. He continually falls back

on cartesians, and his vector work is apt to degenerate into cartesian shorthand. The object of a calculus is not to save printing, and it is no advantage to have an expression condensed into two or three symbols if you have to think it out at length to understand it. Shorthand is not necessarily short-thought, especially if it also involves writing operators as quantities. It is possible to know the meaning of

$$\left(\mu\rho - \frac{\nabla^2}{c\dot{\rho}}\right) \mathrm{H} \text{ where} \frac{1}{\dot{\rho}} \text{ is } \frac{dt}{d},$$

it is also possible to know what is meant by "Boyle was the father of chemistry, and brother to the Earl of Cork." It might be suggested that if Mr. Heaviside wants to make either vector analysis or quaternions simple to physicists, he should avoid the confusion between operators and quantities, and between operation generally and multiplication in particular; or else write an introductory calculus of functions showing where such liberties can be taken with impunity.

Mr. Heaviside has a rooted aversion to 4π. This factor came into the system of units from statics, as the mathematical treatment of electricity was much the same. Mr. Heaviside employs a medium treatment, and thinks that 4π should, therefore, disappear. He thinks that Maxwell and other mathematicians did not know how 4π came about, and thought it was a physical necessity. With his treatment it is an advantage to remove the 4π from its usual place; but it only appears in the denominator elsewhere. It is like the eruption due to a disease: suppress it, and it appears elsewhere. The unsavoury metaphor is not ours. The disease is the area of a unit sphere being 4π. Until Mr. Heaviside can cure that, he cannot really eliminate 4π. He whitewashes 4π whenever it appears in his book, saying that it is not the B.A. 4π of amazing irrationality. When a man refers to his own ideas as alone rational, or based on common-sense, or well-known facts, he is generally wrong.

Mr. Heaviside is, as is well known, a prolific inventor of new terms. He says he hates grammar; he has also a murderous hatred of the Queen's English when inventing terms such as "leakance," "reactance," and "potted." Generally speaking, a writer has no business to insist that his reader shall study a new terminology; but when any one of Mr. Heaviside's reputation invents names which are euphonious and good, they become parts of our language, and we must thank him, especially when his terms are suggestive and systematic. The example is bad though. The English language is capable of improvement; but if every writer is to alter it to suit his ideas, it will not improve. It is a matter of taste which terms should be adopted; many object to voltage and gaussage as unsystematic where ampereage, farradage, &c., are not used. Voltage was originally used to denote the pressure for which lamps, dynamos, &c., were designed by the maker, whatever they were run at. Pressure belongs to the same set of ideas as current, capacity, resistance, and quantity; and if they are used, should also be employed. It is, however, a matter of taste only.

The style is that of Whitman, except that Mr. Heaviside is not affected, and has something to say. The similarity is also noted in the *Philosophical Magazine*. Every line of the book is important, and it is full of interesting digressions on all sorts of subjects. Though the converse may not be true, all clever men have a sense of humour, and it is therefore a pity that scientific writers emulate the ponderous dryness of the theologian. Mr. Heaviside's work bristles with humour of a type which he has invented.

It is generally assumed that a review should be written by a man who could have written the book himself. In the case of a writer of Mr. Heaviside's calibre there is difficulty in getting such reviewers. The real object of a book is, however, to teach not those who know the contents already, but the student, and it may therefore be an advantage to review a book from the student's point of view. This review must, therefore, be taken as from that point of view; that is, as written by a reader who has not devoted a large enough portion of his time to the study of mathematics or mathematical physics to be more than a student of them.

J. SWINBURNE.

RECENT PSYCHOLOGY.

Lectures on Human and Animal Psychology. By Wilhelm Wundt. Translated by J. E. Creighton and E. B. Titchener. Pp. x. 454. (London: Swan Sonnenschein and Co., 1894.)

Grundriss der Psychologie. Von Oswald Külpe. Pp. viii. 478. (Leipzig: W. Engelmann, 1893.)

Introduction to Comparative Psychology. By C. Lloyd Morgan. Pp. xiv. 382. (London: Walter Scott, 1894.)

Psychology for Teachers. By C. Lloyd Morgan. Pp. x. 251. (London: Edward Arnold, 1894.)

Primer of Psychology. By George Trumbull Ladd. Pp. xv. 224. (London: Longmans, Green, and Co., 1894.)

THE translation of Prof. Wundt's well-known lectures is taken from the second revised German edition which appeared in 1892, and is therefore well up to date. It is the first work of the author to appear in English, and the choice made by the translators is a good one; while the book will give to those specially interested in psychology a general sketch of the author's views. Its popular and lucid form will appeal to a wider circle of readers who would hardly care to digest the details and technicalities of the "Grundzüge der physiologischen Psychologie."

The greater part of the book is devoted to human Psychology, especially in its physiological and experimental aspects, and there are several interesting chapters on animal psychology, and a short account of the author's views on hypnotic conditions. Prof. Wundt's own opinions are stated rather more dogmatically than is altogether suitable for an elementary book in a science like psychology; thus, in dealing with intensity of sensation, the validity of the logarithmic formula is very positively enunciated, and it is somewhat surprising to find