in the Kew Herbarium, has been good enough to undertake a critical examination of Crüger's drawings, and compare them carefully with the description and plates of the species in the "Flora Brasiliensis." The result of the investigation is contained in the following note:—

"Crüger's drawings of *Sacoglottis*, Mart. 'Cojon de Burro,' October 13, 1861, agree perfectly with *Sacoglottis amazonica*, Mart. ('Flora Brasiliensis,' vol. xii. pt. 2, p. 449, tab. xcv.) The analyses are very carefully done. The sketch of the base of the leaf, for instance, shows the characteristic two glands which had been overlooked by Martius as well as Urban. As the fruit has not been previously described, it appears desirable to give a description of it drawn up from Crüger's drawings, as well as from the several specimens in the Kew Museum.

"Fructus subdrupaceus, ellipsoideus, $1\frac{1}{2}$-$1\frac{3}{4}$ poll. longus, 1-$1\frac{1}{4}$ poll. latus, exocarpio vix 1 lin. crasso, endocarpio osseo, extus subbullato, cavernis resina impletis abundante, 5-loculari vel saepius ob ovula loculosque 1-4 aborta 4-1-loculari ineunte

Fruit of *Sacoglottis amazonica*, Mart. (after Crüger).

germinatione valvis 5-trigonis ab axi 5-alata semina inter alas in loculis late apertis exhibente sedentibus dehiscente. Semina cylindrica, pollicaria, testa tenui nigro-brunnea, albumine carnoso, embryone centrali, cotyledonibus lineari-oblongis planis, radicula brevi supera.

"The breaking up of the fruit, as described above, takes place also in water-worn specimens, as shown in the fruit collected by Dr. Nicholls. *Sacoglottis amazonica* was previously known only from Teffe or Egas, on the right bank of the middle Amazon, and from the banks of the Tagipurú, a channel in the delta of the Amazon, where it was collected by Martius. It is recorded from St. Vincent, on the authority of Guilding. Specimens from the latter are in the Kew Herbarium, but whether from wild or cultivated plants is not stated. It is also not certain whether they did not come, as many of Guilding's specimens, from Trinidad."—O. STAPF.

SUMMARY.

The story of this interesting drift-fruit is now told. The record of its occurrence has been traced from the year 1605, when it was first figured and described by Clusius, down to 1764, when it was redrawn by Petiver. For about one hundred and fifty years it was successively described by Clusius, Jonston, J. Bauhin, Hans Sloane, and Petiver. From 1764 until 1884, a period of one hundred and twenty years, it appears to have been entirely overlooked. It was, however, once more brought into notice in the latter year, and drifted specimens were obtained within a short period from Jamaica, the South of England, Barbados, the Grenadines (between St. Vincent and Grenada), and Trinidad. The specimen from the latter island was accompanied by careful drawings made by Crüger in 1861, giving particulars not only of the fruit itself, but also of the leaves and flowers. These when carefully compared with the description and plate in the "Flora Brasiliensis," and with specimens in the Kew Herbarium, left no doubt that the plant yielding the Jamaica drift-fruit is *Sacoglottis amazonica*, Mart. This grows very sparingly in the south-eastern portion of Trinidad, where it was collected by Crüger, but is more abundant in the delta of the Amazon, where it was collected by Martius and others. It is evident that from one or both of these localities the fruits are carried by the waters of the Gulf Stream into the Caribbean Sea, and either thrown ashore on the West Indian Islands, or carried still further, as in the case of many other similar fruits, across the North Atlantic, and cast on the shores of Western Europe.

D. MORRIS.

THE PERCEPTION OF LIGHT.[1]

AT a former anniversary I brought before the members of the Institute the subject of the luminiferous ether. It is one of great and growing interest. I mentioned on that occasion how discoveries of very recent date have led us to attribute continually increasing importance, and a widening range of function, to that medium—substance can I call it?—the existence of which was originally assumed as a hypothesis in order to account for the phenomena of light. It is in connection with this last aspect that it relates to what I propose to bring before you to-day.

The wonderful sense of sight, which, to use an expression of Sir John Herschel's, confers upon us to some extent the character of ubiquity, requires two things: in the first place, some means by which those distant bodies which we see are able to affect our own neighbourhood; in the second place, some provision in our own bodies for receiving that influence, and transmitting some sensation to the conscious being.

In my former address I considered the first of these two subjects; to-day I mean to confine myself to the second. This second, even by itself, is, however, far too wide for a single address; selection of some kind is imperatively demanded. Moreover, there are some parts which are accurately known, and may even be made the object of mathematical calculation, while there are others which not merely lie beyond our existing knowledge, but beyond any that we can hope to attain to, at least in this life. Wonderful as is the construction of the eye in all its parts, so far as relates to the formation of images on the retina it acts simply like an optical instrument, like a telescope or microscope, or, more correctly, like the objective of such an instrument, and we may apply our mathematics to tracing the course of the rays through it. On the other hand, even if we knew accurately—which we do not—the nature of the effect which the external agent produces on the ultimate structure of our bodies, there would still remain, shrouded in impenetrable mystery, the nature of the process by which some change in the bodily organism causes a sensation to the conscious being.

Between these two extremes lies a region which has been to some extent explored, and in which a gradual and perhaps at last a very substantial increase to our existing scientific knowledge may be looked upon as probable. The investigation of this region possesses the keen interest which belongs to the discovery of new truths, and the addition thereby made to the stock of human knowledge. It is to this borderland lying between the well known and the unknown, and to certain parts of the structure of the eye having relation to it, that I would for a short time direct your attention to-day.

As I have already intimated, I propose to pass by entirely the functions of the eye acting as a simple optical instrument in forming images on the retina. The explanation of that may be found in all the ordinary text-books, and I will not weary you by repeating what is there to be found, and which is generally familiarly known.

The phenomena of vision show that distinctness of vision is dependent somehow or other in the first instance on the formation of distinct images of external objects on the retina. In that formation, as I have said, the transparent portion of the eye, the cornea, the aqueous humour, the crystalline lens and vitreous humour, plays the part of a lens in an optical instrument. I have said the "formation of the images on the retina"; but the retina is not a mere surface, it has a certain amount of thickness, although it is, on the whole, very thin. We may further inquire on what part of the retina, considered at different depths from the place where it first commences, on which of the various layers into which histologists have divided it, is it that we have reason to think that light first acts on the organism of our bodies in such a manner as ultimately to give us the sensation of vision?

I have said that the retina, as a whole, though very thin, is not a mere surface. If we go from the centre of the eye-ball

1 Presidential Address delivered at the Victoria Institute by Sir G. G. Stokes, F.R.S.

outwards, *i.e.* towards the back of the body, we have first a plexus of very fine nerve-fibres which run along the front of the retina, and ultimately unite in the optic nerve, which runs into the brain. We have also minute blood-vessels, which are essential, apparently, for the growth from its original state, and for the nutrition of the eye-ball, and for the carrying on of the process for which it was designed, viz. that of enabling us to see. Then we have several layers of pulpy transparent substances which have been called ganglions, nuclei, and molecules, mixed with very fine fibres. Some of these are nerve-fibres, others are believed by anatomists to have relation to the fixing of the various parts of the structure to one another, so that they shall not fall to pieces in the rapid motions of the person using the eye.

Outside all, at the back surface of the retina, there is what is called the choroid coat; but between that and the coats I have spoken of is a very remarkable structure which I shall have to say more about. It is called the *bacillary* layer. In this part of the retina we have a vast number of elongated bodies placed closely, side by side. In the human eye, and in the eyes of most animals, they are of two shapes, and have been called accordingly rods and cones. The rods, as the name implies, are cylindrical, and the cones are tapering and are somewhat of the shape of slender peg-tops, the sharp side being turned inwards as regards the way you look, so that the light, in coming from the outside, first meets the bases of the peg-tops, and then goes on towards the point. About the point of these rods and cones, just close to the choroid coat, is a layer of pigment cells which absorb the greater part of the light falling upon them. The rods and cones are transparent, and allow the light to pass through them, passing lengthways. I said the extremities reached to the layer of pigment cells forming a black lining immediately inside the choroid coat. That is true of the rods, but the cones do not reach quite so far, *i.e.* when the eye is in a state of repose, as in darkness; but under the stimulus of light these pigment cells come down, *i.e.* forward, in the direction in which you look, so as to reach the tops of the cones as well as of the rods. I have said that these elements (remember, please, that they point radially in the direction in which you are looking, and lie side by side) are exceedingly numerous. When they are looked on lengthways from the back of the eye when the pigment is removed, they form a sort of mosaic. You may imagine the general structure of them by thinking of the head of the common sunflower in seed. They are arranged side by side, something like the seeds of the sunflower; but they lie so close that the distance between the neighbouring rods or cones, as the case may be, is only about (it varies somewhat from one part of the eye to another) $\frac{4}{1000}$th part of a millimetre, or say about $\frac{1}{6000}$th part of an inch. So numerous are they that a square with sides the tenth of an inch would cover nearly half a million of them.

Now something more about these rods and cones. They are found to be composed of two members or limbs, an inner (nearer the centre of the eye-ball) and an outer. The inner is a transparent-looking body, very much like the other bodies in the neighbourhood. The outer is transparent too; but it is found to be highly refractive. It is longer in the rods than in the cones. The outer segment of the cones may be represented to the mind's eye by thinking of the metallic point of a peg-top. These outer limbs are in both cases readily detached (when the eye is dissected) from the inner, and they separate after a little into laminæ, lying one on the top of the other, perpendicular to the axis of the rod or cone. At the outer end they do not appear to have any continuation, the structure stops. At the inner end (corresponding in the case of the cones with the bulbs of the peg-tops) there come nerve fibres from each of them. These pass through the various layers that I have spoken of; and although the course of them has not actually been traced the whole way, on account of the difficulty of examination of this pulpy structure, it is pretty certain that they join on to those nerve-fibres which line the front surface of the retina, and so pass on, through the optic nerve, to the brain. When I say "pass on" I mean of course as you trace them along; there is no motion in the case. This is a very remarkable structure. Has it any object? What is its object? Now we know by experience that if we have a single point of light exposed to us, the impression is that of a single point of light in the field of view. If there be two such points we have the impression of two luminous points occupying different positions in the field of view. Now two such points may be very close to one another, and yet we still see them as two. It is found that the limit of closeness, beyond which we are unable to distinguish two objects as two, is such that a line drawn between them subtends at the eye an angle of about one minute, or an angle of about $\frac{1}{30}$th part of that subtended by the diameter of the moon. Yet although they exist as close as that, the impression of the two is distinct, and we might have a number of points, each giving a distinct impression. It appears, therefore, that for the purpose of vision it is necessary that stimulations coming from a vast number of independent points, having different bearings from the eye, should, somehow or other, give rise to distinct impressions.

Now if by calculation we trace inwards, to the retina, the course of the axes of two pencils coming respectively from two distant points not far from the centre of the field, it is found that those axes intersect, not exactly in the centre of the eye-ball, but in a point (called the optical centre) a little in front of it, the position of which we can calculate; and the place of either image may be found by joining the external point with the optical centre, and producing the joining line to meet the retina. It is an easy matter now to calculate the distance on the retina of the images of two external points which subtend at the eye a known angle; and it is found that when the external points are so close as only just to be seen as two, the distance of the two images is about the $\frac{4}{1000}$th of a millimetre, just about the distance apart of the cones and rods from one another, lying so closely as I have explained they do. Here, then, it would appear, in this remarkable layer of the retina, we have a provision enabling us to have distinct sensation of a vast number of distinct points in the field of view; and consequently we have reason to suppose that the effect of light, whatever it be, on one of these elements (be it cone or be it rod) gives rise to the sensation of a point; and that the position of that point in the field of view depends upon the position of the element of the bacillary layer which has been affected by the light coming from the point. Moreover in the nerve-fibres which come from the anterior ends of the rods and cones we appear to have a provision for communicating, through the optic nerve, to the brain, the influence, or an indication of the influence which light exerts on one of these elements.

Now I have mentioned one argument for believing that this remarkable bacillary layer is that in which light, which previously merely passed through the eye as it would through an optical instrument, acts in some manner on the organism so as to give rise to stimulation of the nerves which convey to us the sensation of vision. The argument, so far, is a sort of *à priori* one, but it has been remarkably confirmed by an experiment of H. Müller's, made by means of Purkinje's figures.

When in a room which is not quite dark we look with one eye towards a moderately illuminated wall with uniform surface, and holding a candle to one side of the eye move it up and down, there is seen in the field of view a figure branching like seaweed. This is the shadow of the blood-vessels of the retina. That the candle requires to be moved in order to show the figure, is explained by the consideration that the shadow is not black, but only darker than its neighbourhood, and when the light is steady the exhaustion of the eye for that part of the field which lies beside the shadow tends to equalise the apparent illumination of the parts in and out of shadow; whereas when the candle is moved the shadow falls on a new place which had been in full light and therefore partially exhausted, and the previous exhaustion and the new partial interception of light falling on that place contribute to make the shadow sensible.

The existence of a shadow shows already that the percipient layer of the retina must lie behind the blood-vessels. But we may go a step further. By suitable methods of illumination we may cause two spots on the surface of the eye-ball, whose positions can be determined from the circumstances of the experiment, to be alternately virtually the sources of the light which casts the shadow, and the places in the field of view of the shadows of the same vessel in the two positions of the illuminating source can be marked. It is then only a question of similar triangles to determine how far behind the blood-vessels lies the percipient layer, and the distance thus calculated is found to agree, within the limits of errors of observation, with the distance of the bacillary layer as determined by microscopic examination of a dissected eye.

I have said as you go backward from the centre of the eye-ball, you have, in front of the rest of the retina, a plexus, as it is called, of nerve-fibres lying side by side, something like the threads in a skein of silk, but gradually leading onwards to the optic nerve. Light passes across these, but it does not excite the nerves in passing through them. The nerves are transparent, and the light produces no effect upon them directly. If it did, your whole field of view would be confused, because it is known that when a nerve is excited the sensation is referred to a particular part no matter where the nerve may be affected. Suppose you could isolate, say in the thigh, a particular nerve leading to the great toe, and pinch it without hurting its neighbours, you would feel the pinch not where the nerve is pinched, but in the great toe. So, here, if these nerve-fibres were excited by the passage of light through them, then the sensation corresponding to the excitement of a particular nerve-fibre, which would be that of a definite point in the field of view, would be excited by an external luminous point lying anywhere in the curve in which the surface generated by a straight line passing through the optical centre and intersecting the fibre in question would cut what we may call the celestial sphere, and the correspondence between the subjective points in the field of view and objective external points would be lost. And the fact that the visual nerves are not affected by light which passes across them is further shown by the well-known experiment of the blind spot, where the optic axis passes out of the eye-ball, not in the axis of vision but to one side, towards the nose, so that an object whose image falls on the blind spot of one eye is seen by means of the other.

But now comes a question, and here we enter on uncertain and debated ground—How is it that the nerves are stimulated by the light at all?

We have reason to believe that these rods and cones form the means by which the light, acting on them, causes the stimulation of the nerve. As I have said, they consist of two elements, an inner and outer; the outer from the centre of the eye, *i.e.* the inner as regards the body, being of that remarkable structure which I have described. It has been questioned which of these two elements it is that you are to regard as the percipient organ. I do not know that physiologists have decided that question. I have looked into a paper of Max Schultze's—in fact I have it on the table—and he inclines to the opinion that it is the outer element. Now is there anything in the outer element which can conceivably form a means of stimulation of the nerve, when that element is acted on by light?

I have spoken of the way in which it is composed of laminæ which come to pieces when dissected, after a certain amount of maceration. I do not know whether it may not be rash to say what I am about to say, because I do not know that physiologists have suggested it—it is merely an idea which occurred to myself, so you must take it for what it is worth. I was reading an account of the electric organ of electrical fishes, such as the torpedo. It is a very remarkable organ, occupying a considerable space in these fishes. It has a columnar structure, and the column again consists of laminæ placed one over the other. It has a structure which may roughly be compared to that of the basaltic columns in the Giant's Causeway, only here you must think of laminæ as more numerous and not having that curved surface shown in the Giant's Causeway. Now nobody questions that somehow or other this is an organ by means of which these fishes are enabled to give a shock, and the idea, of course, is suggested, are not these laminæ like the plates of a battery? Is not one of these columns, roughly speaking, something like a galvanic battery? But how the battery is charged and discharged we do not know. In this case it depends, no doubt, on the will of the animal as to what he does, and nobody knows how he brings that about.

Now it strikes me that there is a remarkable apparent analogy between the outer member of the rods and cones, and these columns in electrical fishes. This gives rise to the suspicion that possibly these outer members may act the part of a microscopic battery, being charged somehow or other. But how are they to be charged? Well, before I go on to enter into any speculation on that I may mention that some years ago Prof. Dewar and Mr. McKendrick made some remarkable experiments, the results of which are given in a paper published in the *Transactions* of the Royal Society of Edinburgh. When an eye is dissected out, and the cornea is connected through a wire with non-polarising electrodes to the middle of the section of the optic nerve, the wire being led through a delicate galvanometer, it is found that there is a certain amount of electric current passing. Now it was found that when the eye (having been in darkness) was allowed to have light shining upon it, there was a change in this current, and a change again when the light was cut off. It is true that the total change was only a small fraction of the whole; but still that there should be any change at all produced by the action of light is a remarkable thing. It looks very much as if the stimulation of the nerve had something or other to do with the production of electric currents; but those, if they are produced, we must suppose to be produced in some way by the action of light. How may we imagine light to act so as to produce them? It has been discovered that in the layer of pigment cells in the retina there is a substance, called visual purple, of a purple colour, which is acted on by light, and is made first yellow and then nearly colourless. We have thus a substance that is capable of being acted upon by light, as very many substances are. I do not say that it is by any means proved that that is the substance, or even that there is any substance, which is acted upon by light in the way demanded; yet it seems very probable that the change produced by the action of light, whether it be on visual purple, or some other substance associated with it, may give rise to something which may, so to speak, charge this microscopic battery and stimulate the nerve-fibre which is attached to it. We know the rate of the vibrations of light of various kinds; and the rapidity of vibrations is so enormous, ranging about 400 millions of millions of vibrations in a second, that we can hardly imagine that the organism of our bodies is calculated to be set in vibration in a corresponding period. In that respect the sense of sight differs notably from the sense of hearing. In hearing the tympanum of the ear is thrown into vibration, and the vibrations are not so enormous in number in such a time as one second but that the corresponding nerves may actually be mechanically agitated, and thereby in some way stimulated. We can hardly imagine that the visual nerves are acted upon in this sort of way directly by the luminous vibrations, but they may be indirectly. Here, again, I may throw out a possible conjecture, though I am less disposed to receive it myself than that which I have just mentioned. We know there are substances which when acted upon by light continue to shine in the dark. In some cases the action ceases almost instantly after the exciting light is cut off; for instance, a solution of the salts of quinine, where the rapidity of cessation of the effect is amply sufficient to tally with the rapidity of cessation of visual sensation when light is cut off.

There are various other matters connected with the perception of light which are of great importance to our well-being and to our enjoyment which I have not ventured to touch upon at all. It would take a great deal too long to go into two which I will only just mention. One is the provision in the two eyes, and in the muscles which move them, which enables us to obtain single vision notwithstanding that the two eyes are at work. Nothing is easier than to obtain double vision in which the images seen by means of two eyes occupy different positions in the field of view. There are very remarkable contrivances for bringing about singleness of vision in the habitual use of both eyes.

Then, again, we do not see light merely as light, but we see a great variety of colour. We can distinguish one light from another light by its colour, and not by its intensity only. It would take me a great deal too long to give you any idea of what is known (which after all is not much) as to the way in which that is effected.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Woodwardian Museum has been greatly enriched by the generosity of Prof. T. Wiltshire, Treasurer of the Geological Society and Secretary of the Palæontographical Society, who has presented to the University a large collection of Cretaceous fossils. The collection includes nearly all the known British species, as well as many not yet described. This addition will probably make the Woodwardian collection of Cretaceous fossils the finest in the country. The thanks of the University have been voted to Prof. Wiltshire, who is himself a Cambridge graduate.

Sir William Turner, F.R.S., of Edinburgh, has been appointed an Elector to the chair of Anatomy, and Lord Walsingham, F.R.S., an Elector to the chair of Zoology and Comparative Anatomy, in place of the late Right Hon. T. H. Huxley.

The Vice-Chancellor, Mr. C. Smith, Master of Sidney Sussex College, is suffering from the shock of a fall from his bicycle last week, and will probably be unable to resume his duties for some