

(*Cebus fatuellus*) from Guiana, a Red-billed Toucan (*Ramphastos erythoryhnchus*) from Cayenne, purchased; a Smooth Snake (*Coronella levis*), European, received in exchange.

OUR ASTRONOMICAL COLUMN

DEFINITIVE COMET-ORBITS.—I. The fourth comet of 1874 (Coggia, April 17). Dr. Hepperger, of Vienna, has investigated the orbit of this comet from the whole extent of observation, founding his work upon 17 normals from 638 observed positions. He finds the orbit an ellipse with period of 13,708 years, and considers that his results exclude equally a parabola and any ellipse with a revolution shorter than 8000 years. The aphelion distance is 1144.9 (the earth's mean distance from the sun being taken as unity), at the descending node the radius-vector is 0.717, near the orbit of Venus, and at ascending node it is 11.734. Coggia's comet became visible to the naked eye at the beginning of June, and so continued until it was lost in these latitudes in the middle of July, when the tail had gradually increased to 23°.

2. Definitive elements have also been determined for the second comet of 1847, by M. Folke Engstrom of Lund. The comet was discovered by Colla at Parma, on May 7, and was last observed by the late Mr. Lassell at Starfield, Liverpool, on December 30, or over a period of nearly eight months. The orbit is chiefly remarkable for the large perihelion distance, 2.115, which has been exceeded in very few cases. The resulting elements are hyperbolic $e = 1.0006549$. So far as we know this is the only instance where the latest observations for position have been obtained with a reflector, the statement that has been more than once made that Halley's comet in 1836 was last observed by Sir John Herschel with his 20-foot reflector at Feldhausen, Cape Colony, being a mistake; the last observation was made by Lamont with the 11-inch refractor at Munich on May 17.

THE VARIABLE STAR ALGOL.—The following are the Greenwich times of minima of Algol, occurring before 15h., during the last quarter of the present year, taking Prof. Winnecke's ephemeris as authority:—

h. m.	h. m.	h. m.
Oct. 14, 13 0	Nov. 9, 8 20	Dec. 16, 14 55
17, 9 49	26, 13 13	19, 11 44
20, 6 38	29, 10 2	22, 8 33
Nov. 3, 14 42	Dec. 2, 6 51	25, 5 22
6, 11 31		

THE MOTION OF 61 CYGNI.—The following formulæ appear to represent the observations of this remarkable system up to the present epoch within about their probable errors; P is the angle of position, D the distance:—

$$D \sin P = + 16.4657 + [8.63013] (t - 1850.0)$$

$$D \cos P = - 3.6892 - [9.27178] (t - 1850.0)$$

Hence we find—

	Diff. R. A.	Diff. Decl.	
1753.8	+ 1.2	- 1.7	Bradley.
1778	+ 1.9	- 0.2	Ch. Mayer.
	$\Delta P (c - o)$	ΔD	
1781.85	+ 2.4	- 0.04	Herschel I.
1812.30	- 1.7	- 0.69	Bessel.
1822.26	- 0.1	+ 0.14	Struve and Herschel II.
1830.84	0.0	+ 0.01	Bessel.
1842.70	- 0.3	- 0.29	Dawes and Struve.
1856.37	- 0.1	- 0.29	Demb., Jacob, Secchi, 1854-1857.
1867.15	0.0	- 0.16	Knott, Demb., Duner, 1866-67.
1877.47	0.0	0.00	Hall, Demb., Duner, 1875-79.
1881.45	0.0	- 0.01	Jedrzejewicz.

And for comparison with measures about this epoch:—

	P.	D.
1882.5	118.50	20.469
1883.5	119.08	20.476

THE COMET OF 1763.—The comet observed by Dunlop at Paramatta in 1833 has been referred to as affording an instance

of near approach to the earth's orbit at both nodes; according to Dr. Hartwig's elements the distance at ascending node is 0.092, and at descending node 0.186. But a much more noticeable case is offered by the comet of 1763. In Burckhardt's ellipse we find the distance at ascending node 0.0315, and at descending node 0.0252, the time occupied in passing from node to node is 77.2 days.

THE EXCITABILITY OF PLANTS¹

II.

THE complete knowledge we have gained from our study of the anther filaments of *Centaurea* of the mechanism of the excitable plant cell, can be applied to every other known example of irritability in the organs of plants, and particularly to that most remarkable of all such structures, the leaf of *Dionæa muscipula*. Although I described the structure of the leaf just eight years ago in this room, I will occupy a moment in repeating the description. The blade of the leaf is united on to the stalk by a little cylindrical joint. Here are two models, in one of which the leaf is represented in its closed state, in the other in which it is in its unexcited or open state. The leaf is everywhere contractile—that is, excitable by transmission, but not everywhere susceptible of direct excitation—or, in common language, sensitive. It is provided with special organs, of which we do not find the counterpart in any of the plants to which reference has been made, for the reception of external impressions—organs which, from their structure and position, can have no other function.

The action of the leaf, to which the plant owes its name, and by which it seizes its prey, is, in its general character, too well

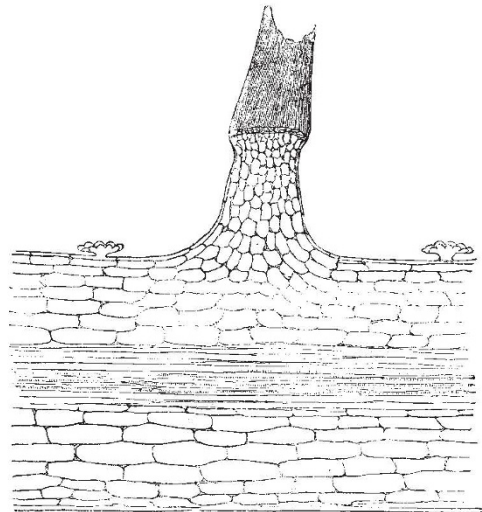


FIG. 6.—Transverse section of lobe of leaf of *Dionæa* comprising the root of a sensitive hair.

known to require description. In the shortest possible terms, it is the sudden change of the outer surface of each lobe of the leaf from convex to concave, and at the same time the crossing of the two series of marginal hairs, as the fingers cross when the hands are clasped. What I desire to show with respect to it is, that here also the agents are individual cells—that is, that the individual elements out of which the whole structure is built are the immediate agents in the production of the movement.

A cross-section of the leaf shows the following facts: If the section be made in the direction of the parallel fibro-vascular bundles which run out from the mid-rib nearly at right angles, and happen to include one of these bundles, it is seen that it consists of three parts, viz. the fibro-vascular bundle in the middle and equidistant from both borders; of the cylindrical cells of the parenchyma on either side, and of an external and internal epidermis. The external epidermis is smooth and glistening, and its cells possess thicker walls than those on the opposite surface.

¹ Lecture delivered at the Royal Institution June 9, 1882, by Prof. Eudon Sanderson, F.R.S. Continued from p. 356.

The most remarkable feature of the internal surface is, that it possesses the excitable hairs, three on each side, which in *Dionæa* are the starting-points of the excitatory process whenever it is stimulated by touch, as is normally the case when the leaf is visited by insects; for experiment shows that although the whole of the leaf can be excited either by pressure or by the passage of an induction current, the hairs exclusively are excited by touch. It is therefore of great interest to know their structure and their relation to the excitable cells of the parenchyma, with which they are in so remarkable a relation physiologically. In sections such as that which we will now project on the screen (Fig. 6), it is seen that each hair springs from a cushion which con-

sists of minute nucleated cells inclosed by epidermis; and that if we follow this structure into the depth of the leaf, its central cells gradually become larger, until they are indistinguishable from those of the ordinary parenchyma of the leaf. By these cells it must be admitted that the endowment of excitability is possessed in a higher degree than by the ordinary cells of the parenchyma, so that for a moment one is tempted to assign to them functions corresponding to those of motor centres in animal structures (particularly in the heart). There is, however, no reason for attributing to them endowments which differ in kind from those we have already assigned to the excitable plant cell.

The fact that the excitable organs are exclusively on the



FIG. 7.

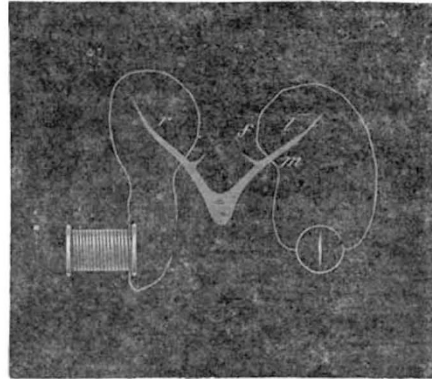


FIG. 8.

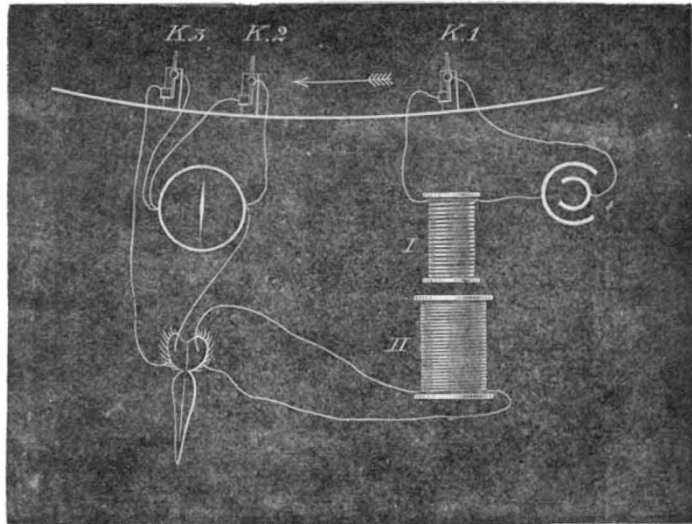


FIG. 9.

FIG. 7.—*Dionæa* leaf fixed so as to prevent its closing. (From a photograph). FIG. 8.—Diagram of ideal transverse section of lamina of leaf of *Dionæa*. The needle inclosed in a circle represents the electrometer which in the experiment described was substituted for the galvanometer. On the opposite side is shown the secondary coil of the inductorium. *m* is in connection with the capillary, *f* with the sulphuric acid of the electrometer. FIG. 9.—Diagram of the pendulum-rheotome. *k*₁, *k*₂, and *k*₃ are the keys referred to. I. and II. represent respectively the primary and secondary coils of the inductorium. The leaf galvanometer, battery, &c., will be easily recognised.

internal surface of the lobe, suggests that although the parenchyma of the inside has apparently the same structure, it has not the same function as that of the outside—that is, that although the cells of the outer layers are just like those of the inner, they are either not excitable at all, or are so in a much less degree. In this way only can we account for the bending inwards of the lobe. In the unexcited state both layers are equally turgid; as the effect of excitation the internal layers become limp, the external remaining tense and distended.

I will now endeavour to illustrate the motions of the leaf by projecting them on the screen. Here are several leaves which have been prepared by attaching one of the lobes to a cork support; the other is free, but a very small concave mirror

has been attached to its external surface near the margin. The image of the light which falls on the mirror is reflected on the wall behind me. In this way the slightest movement of the lobe is displayed. By this contrivance I wish to show you two things—first that a very appreciable time elapses between the excitation and the mechanical effect; and secondly, that when the leaf is subjected to a series of very gentle excitations, the effects accumulate until the leaf closes. This we hope to show by bringing down a camel hair pencil several times in succession on a sensitive hair, doing it so deftly that at the first touch the lobe will scarcely move at all. At each successive touch it will bend more than at the preceding one, until you see the lever suddenly rise, indicating that the leaf has closed. The purpose which I have

in view is to demonstrate the contrast between the motion of the leaf and muscular contraction. A muscle in contracting acts as one organ—at once. The motion of the leaf is the result of the action of many hundred independent cells, all of which may act together, but may not. In either case they take a great deal longer to think about it; for during a period after excitation, which amounts at ordinary summer temperature to about a second, the leaf remains absolutely motionless.

And now we have to inquire what happens during this period of delay. There are two things which we may assume as certain without further proof, namely, first that something happens; for when I see a certain movement followed after a time invariably by another, I am quite sure that the chain between cause and effect is a continuous one, although the links may be invisible; and secondly, that this invisible change has its seat in the protoplasm of each of the excitable cells.

We have already seen that in muscle this latent state of excitation is not without its concomitant sign—the excitatory electrical disturbance, and I have now to show you that this, which is the sole physical characteristic of the excitatory process in animal tissues, manifests itself with equal constancy and under the same conditions in plants.

It will be unnecessary for my present purpose to enter into any details as to the nature of the electrical change; it will be sufficient to demonstrate with respect to it, first, that when observed under normal physiological conditions, its phenomena are always conformable to certain easily defined characters; secondly, that it culminates before any mechanical effect of excitation is observable, and consequently occupies, for the most

part, the period of latent excitation already referred to; and thirdly, that it is transmitted with extreme rapidity from one lobe of the leaf to the opposite. Of these three propositions, it will be convenient to begin with the second. On the left-hand screen is projected the mercurial column of the capillary electrometer of Lippmann. The instrument which we use this evening is one of great sensibility, given me by my friend Prof. Lovén of Stockholm. The capillary electrometer possesses a property which for our purpose is invaluable—that of responding instantaneously to electrical changes of extremely short duration. We cannot better illustrate this than by connecting the wires of the telephone with its terminals. If I press in the telephone plate I produce an instantaneous difference between the terminals in one direction, and in the opposite when I remove the pressure. You see how beautifully the mercurial column responds.

We now proceed to connect the terminals with the opposite sides of a leaf, so that by means of the mirror we can observe the moments at which the leaf begins to close and the first movement of the mercurial column, both being projected on the same screen. We shall see that the mercurial column responds (so to speak) long before the mirror. The difference of time will be about a second.

We now take another leaf which, with the plants of which it forms part, is contained in this little stove, at a temperature of about 32° C. Our object being to subject the leaf to a succession of excitations, the effects of which would of course be to determine its closure, we prevent this by placing a little beam of dry wood across it, and fixing the ends of the beam with plaster of Paris to the marginal hairs of each lobe. At the same time,

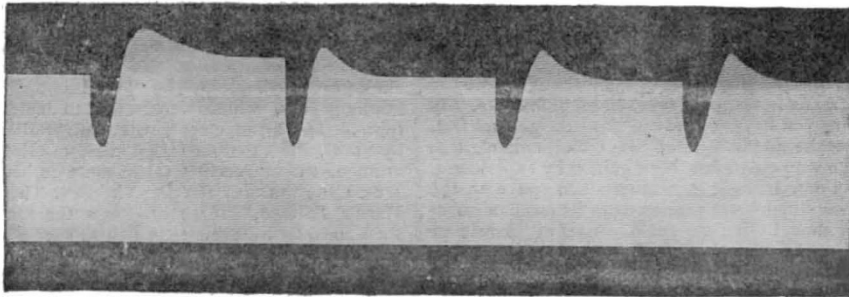


FIG. 10.—Copy of photograph of the excursions of the capillary electrometer as projected on a sensitive plate moving at the rate of $\frac{1}{3}$ centimetre per second. The four "excitatory variations" shown were due to as many touches of a sensitive hair of the lobe opposite to that of which the opposite surfaces were connected with the terminals of the instrument.

wedges of plaster are introduced in the gap between the lobes at either end of the mid-rib. [The leaf so fixed was projected on the screen (Fig. 7).] This having been done, we can excite the leaf any number of times without its moving; and we know that we actually excite it by observing the same electrical effect which, in the first leaf experimented on, preceded the movement of the lobe.

And now I beg you to notice what the nature of the experiment is. The diagram (Fig. 8) shows the position of the electrodes by which the opposite surfaces are connected with the terminals of the electrometer. You will notice that they are applied to opposite points of the internal and external surfaces of the right lobe, and that the left lobe is excited. The experiment consists in this. By the electrodes near *r*, an induction shock passes through the right lobe. Apparently at the same moment the electrometer, which is in relation with the opposite lobe, responds. I say apparently, because in reality we know that the response does not begin until about $\frac{3}{100}$ th of a second later. We prove this by a mode of experimentation which is of too delicate a nature to be repeated here. I will explain the mode of action of the instrument used by a diagram (Fig. 9) which represents a pendulum in the act of swinging from left to right. As it does so, it opens in succession three keys, of which the first is interpolated in the primary circuit of the induction apparatus which serves to excite the leaf; the second breaks a derivation wire which short-circuits the electrodes, so that, so long as it is closed, no current passes to the galvanometer, which in this experiment takes the place of the electrometer, while the third breaks the galvanometric circuit. Consequently the opposite surfaces of the leaf are in communication with the galvanometer

only between the opening of the second and third keys. These three keys can be placed at any desired distance from one another. If they are so placed that the galvanometer circuit is closed $\frac{1}{100}$ th of a second after excitation, and opened $\frac{3}{100}$ th of a second, and it is found that there is no effect, it is certain that the electrical disturbance does not begin at the part of the leaf which is interpolated between the galvanometer electrodes until at least $\frac{3}{100}$ th of a second after the excitation. If, on extending the period of closure to $\frac{4}{100}$ th of a second, the effect becomes observable, you are certain that the disturbance begins between three and four hundredths of a second after excitation.

By this method we have learnt, first, that even when the seat of excitation is as near as possible to the led off spot, there is a measurable delay, and secondly, that its duration varies with the distance which the excitation effect has to travel so as to indicate that, in a warm stove, the rate of transmission is something like 200 millimeters per second. It is, consequently, comparable with the rate of transmission of the excitatory electrical disturbance in the heart of the frog.

And now I come to my last point, namely, that the electrical change has always the same character under the same conditions. You have already seen that when the method used is that which I have indicated, the electrical effect consists of two phases, in the first of which the external surface of the leaf becomes negative to the internal. I will now exhibit this in another way. Many present have probably seen in a recent number of NATURE reproductions of photographs recently taken by M. Marey, of the phases of the flight of birds. If the movement of a bird's wing can be photographed you will easily imagine that we can also obtain light-pictures of such a movement as that of the electro-

meter column. You have only to imagine a sensitive plate moving at a uniformly rapid rate taking the place of the screen, and you have as the result the photograph (Fig. 10) which I show. Here are the electrical effects of several successive excitations recorded by light with unerring exactitude. In each, the diphasic character is distinct, and you see that the first or negative phase lasts less than a second, but that the positive, of which the extent is much less, is so prolonged that before it has had time to subside it is cut off by another excitation.

It would have been gratifying to me, had it been possible, to exhibit to you other interesting facts relating to the excitatory process in our leaf. It has, I trust, been made clear to you that the mechanism of plant motion is entirely different from that of animal motion. But obvious and well marked as this difference is, it is nevertheless not essential, for it depends not on difference of quality between the fundamental chemical processes of plant and animal protoplasm, but merely on difference of rate or intensity. Both in the plant and in the animal, work springs out of the chemical transformation of material, but in the plant the process is relatively so slow that it must necessarily store up energy, not in the form of chemical compounds capable of producing work by their disintegration, but in the mechanical tension of elastic membranes. The plant cell uses its material continually in tightening springs which it has the power of letting off at any required moment by virtue of that wonderful property of excitability which we have been studying this evening. Animal contractile protoplasm, and particularly that of muscle, does work only when required, and in doing so, uses its material directly. That this difference, great as it is, is not essential, we may learn further from the consideration that in those slow motions of the growing parts of plants which form the subject of Mr. Darwin's book, "On the Movements of Plants," there is no such storage of energy in tension of elastic membrane, there being plenty of time for the immediate transformation of chemical into mechanical work.

I have now concluded all that I have to say about the way in which plants and animals respond to external influences. In this evening's lecture you have seen exemplified the general fact, applicable alike to the physiology of plant and animal, that whatever knowledge we possess has been gained by experiment. In speaking of *Mimosa*, I might have entertained you with the ingenious conjectures which were formed as to its mechanism at a time when it was thought that we could arrive at knowledge by reasoning backwards—that is, by inferring from the structure of living mechanism what its function is likely to be. In certain branches of physiology something has been learnt by this plan, but as regards our present investigation, almost nothing, nor indeed could anything have been learnt. Everywhere we find that nature's means are adapted to her ends, and the more perfectly, the better we know them. But, with rare exceptions, knowledge is got only by actually seeing her at work, for which purpose, if, as constantly happens, she uses concealment, we must tear off the veil, as you have seen this evening, by force. Have we the right to assume this aggressive attitude? Ought we not rather to maintain one of reverent contemplation—waiting till the truth comes to us?

I will not attempt to answer this question, for no thoughtful person ever asked it in earnest. Another question lies behind it, which is a deeper and a much older one. Is it worth while? Is the knowledge we seek worth having when we have got it? Notwithstanding that so recently even those who are least conversant with our work have been compelled to acknowledge the beauty and completeness of a life devoted to biological studies, still the question is pressed upon us every hour—How can you think of spending days in striving to unravel the mechanism of a leaf, when you know all the time that if there were no such thing as *Dionaea*, the world would not be less virtuous or less happy? That is a question which I willingly leave to those who put it. From their point of view it does not admit of an answer; from mine it does not require one. They must go on seeking for and finding virtue and happiness after their fashion; we must go on after ours, striving by patient continuance in earnest work, to learn year by year some new truth of nature, or to understand some old one better. In so doing, we believe that we also have our reward.

THE BRITISH ASSOCIATION REPORTS

Third Report of the Committee appointed for the Purpose of Reporting on Fossil Polyzoa (Jurassic Species—British Area

only). Drawn up by Mr. Vine (Secretary).—A partial examination of the Jurassic Polyzoa was made by Goldfuss (*Petrifacata Germania*, 1826-33), but the author is not aware whether he had any English examples of the types described and figured by him. With the exception of the *Aulopora*, all the types are foreign, and he does not find any reference to British species in his text. In the "Geological Manual" of De la Beche, published in 1832, a list of species is given, but only two are named as found within the British area—*Cellipora orbiculata*, Goldfuss (= *Berenicea*, Lamouroux), and *Millepora straminea*, Phill. In the "Geology of York," ed. 1835, Phillips gave three species only—*M. straminea*, *Cellarea Smithii* (*Hippothoa* (?), Morris's Catalogue), Scarborough, and an undescribed *Retipora* (?). When, in 1843, Prof. Morris published his "Catalogue of British Fossils," there was a large increase of species, but many of these had not been thoroughly worked. In 1854, Jules Haime examined critically the whole of the Jurassic Polyzoa then known, and many English naturalists furnished him with material from their own cabinets so as to enable him to correlate British and foreign types. Lamouroux, Defranc, Milne Edwards, Michelin, Blainville, and D'Orbigny have published descriptions of Jurassic species, and a list of these, so far as possible, will be given at the end of this report. Prof. D. Braun, by the publication of his paper on species found in the neighbourhood of Metz, added materially to our knowledge of French Jurassic types, and later foreign authors, Dumortier Waagen and others, have increased the number of described species. Since the publication of Haime's work, much valuable material has been accumulating in the cabinets of collectors, and Mr. Vine willingly draw up a monograph if desired to do so. In the meantime he offers, in the following report, a rather compact analysis of genera and species known by name or otherwise to the palæontologist.

Classification.—Haime's arrangements of the Jurassic Polyzoa is very simple; all his species, excepting two, are placed in one family, the *Tubuliporidae*. In the "Crag Polyzoa," 1859, Prof. Busk gave a synopsis of the "Cyclostomata," arranged in eight family groups, which were made to include several Mesozoic types. This arrangement, with a slight alteration, was followed by Smitt, Busk to some extent accepting the modification for the arrangement of recent Cyclostomata in his later work ("Brit. Mus. Cat.," pt. iii., 1875). The Rev. Thomas Hincks ("Brit. Marine Polyzoa," 1880) disallows the family arrangement of Busk in so far as it relates to British species. The *Tubuliporidae*, Hincks, include, in part, three of the families of Busk. In this report Mr. Vine follows Hincks as far as he is able to do so, as many of the Jurassic species may be included in the family *Tubuliporidae* as now described. It will, however, in the present state of our knowledge at least, be impossible to arrange the species stratigraphically, as many, having the same type of cell, range from the Lias upwards. As far as the author is able to do so, he gives the range of the species, beginning, of course, with the lowest strata.

CLASS POLYZOEA. Sub-order *Cyclostomata*, Busk. Fam. I. *Crisida*, Busk.—No fossils belonging to this family are at present known to have existed in the Jurassic epoch.

FAM. II, 1880. *Tubuliporidae*, Hincks.—*Zoarium* entirely adherent, or more or less free and erect, multiform, often linear, or flabellate, or lobate, sometimes cylindrical. *Zoecia* tubular, disposed in contiguous series or in single lines. *Oecium*, an inflation of the surface of the zoarium at certain points, or a modified cell" (vol. i. p. 424).

1825. *Stomatopora*, Bronn. 1821. *Alecto*, Lamx.; 1826, *Aulopora* (pars), Goldf.—The Reporter has already done partial justice to the universal *Stomatopora*, found in the Palæozoic rocks of this and other countries. He has again studied the species described by James Hall, Prof. Nicholson, and himself, and he cannot, at present, detect any generic character in the species that may be used by the systematic palæontologist to separate the Palæozoic from the Mesozoic types. He must, therefore, regard the *Stomatopora* of the two epochs as one, though the sequence is broken in the Palæozoic—no species having as yet, he believes, been recorded from the Carboniferous series of this or any other country.

In our modern classification (Hincks) we have a sub-genus, *Proboscina*, which links together the genera *Stomatopora* and *Tubulipora*. Haime's second genus is also called *Proboscina*, but there seems to me to be a great difference between the recent and fossil species. The type of the recent sub-genus *Stomatopora incrassata*, Smitt, is a very peculiar species as regards the cells, and he knows of no Jurassic type that can compare with it.