TRANSLATIONS.

On the IMPREGNATION *and* GERMINATION *of* ALGÆ. By M. PRINGSHEIM. (Abridged from the Reports of the Berlin Academy.)

THE existence of sexuality in the vegetable kingdom, though at first surmised simply upon a presumed analogy in this respect between animals and plants, and long a disputed point in science, has for some time been admitted as an indisputable fact. In the *Phanerogamia* especially, the necessity of the conjunction of the pollen tube and the ovule for the production of the embryo can no longer be denied by any one. Observations and experiments whose results admit of no dispute, have established this fact, although opinions may vary as to the *essential nature* of the act of impregnation.

The sexual organs of the higher *Cryptogamia* also are known; but with respect to the mode in which the respective organs participate *materially* in the act of impregnation, and even as regards the *necessity* of their co-operation, we possess at present little more than vague surmises.

In the *Florideæ*, *Fucoideæ*, *Lichens*, and *Fungi*, older and more recent researches have, at most, merely indicated the existence of organs to which sexual functions may possibly be assigned.

The latest endeavours, lastly, to demonstrate the existence of *antheridia* in the fresh-water *Algæ*, with the exception of certain fortunate indications, to which I shall return, may be said to have wholly failed.

This condition, however, of our knowledge, with respect to the sexuality of plants, cannot be regarded as very encouraging. For, admitting that, in order to prove the existence of sexuality it is not sufficient to show the presence of different organs, to which sexual functions may by possibility belong, but also to demonstrate the co-operation of these organs in the formation of the seed or of the young plant; it is obvious that the sexuality of plants, even in that division of the vegetable kingdom in which the organs to which the sexual function has been assigned are already known, has not been demonstrated with that degree of certainty which admits of no doubts being entertained. The grounds upon which the existence of sexual relations in the *Cryptogamia*, has been assumed, properly reside only in the analogy between

the bodies contained in the *antheridia* and the spermatic filaments in animals; and again, in a few isolated observations on the sterility of female Mosses and *Rhizocarpeæ* in the absence of the male plants or organs; and lastly, in the occurrence of hybrid forms among Ferns. All these phenomena, allow the true nature of the *antheridia* to be assumed with great probability, but they are insufficient to afford a scientific proof of it.

What has been wanting for a clear and convincing proof is the demonstration of at least a single instance, in which the *entrance* of the vegetable *spermatozoids* into the female organ, and their influence thereupon may be seen with perfect distinctness and in a way readily at the command of any observer. This requirement, however, is not fulfilled by our observations with respect to the process in the sexual organs in either the higher or the lower *cryptogams*.

I do not deny the value of Thuret's researches, which show, in the way of experiment, the sexuality of the *Fucaceæ;* but in morphological processes, direct visual observation of the process is necessarily of greater value than experiments which always leave room for some degree of doubt. Besides this, Thuret has merely stated the results of his experiments, and has not communicated the precise conditions under which they were instituted. Experimental researches of this kind, may, it is true, show the necessary existence of two kinds of organs for the formation of the young plant, but they throw no light upon the *essential nature of the act of fertilization.*

I am equally disposed to recognize the value of Suminski's statements, who says that he has witnessed the entrance of the spermatozoids into the *archegonium* of Ferns, in *Pteris serrulata;* as well as the importance of Hofmeister's observation, who has noticed the same thing in *Aspidium filix mas.* But in both these instances the tissue surrounding the *archegonium* opposes such difficulties to precise observation, and the phenomenon is so little under the control of the inquirer, that the witnessing of this occurrence can only be regarded as a rare piece of good fortune in an individual observer. Such instances are, certainly, wholly unfitted to constitute the basis of a general scientific conviction; leaving altogether out of question, the circumstance that Suminski's observations have received much contradiction, and that, in any case, he has been deceived as to the part played by the spermatic filaments in the *archegonium.*

It must, therefore, be regarded as a particularly fortunate circumstance, that I have succeeded in witnessing the process in a plant, in which it was possible to observe the penetration

of the spermatozoids into the female organ, with the utmost distinctness and clearness, even into the minutest details of the proceeding; in a plant, in fact, so happily organized that the fertilizing organs may be directly observed without injury to it in its natural condition; and in which, lastly, the female organ, owing to its transparency, offers such a slight obstacle to observation that the motion of the spermatozoids, within it, may be closely watched for hours together, so long as it lasts. I have noticed the gradual completion of both sexual organs so far, as to be enabled to describe the conditions presented in them, which immediately precede the commencement of the act of impregnation. These circumstances place the phenomenon so much under the control of the observer, that he is able previously to determine the time of the commencement of the phenomenon, and in a condition readily to demonstrate the whole act of impregnation before others. Lastly, since I have made these observations in *Vaucheria sessilis*, one of the lowest of the fresh-water *Algæ*, it would appear that the process of impregnation is at present more precisely known in one of the lowest divisions of the vegetable kingdom, than it is in any of the other higher plants, or in any animal; nor does it, furthermore, scarcely admit of doubt, that *sex is a universal property of all organisms, manifesting a wonderful analogy in the most highly organized animals, as well as in the simplest cellular plants.*

1. The *Vaucheria*, besides the asexual multiplication by zoospores, also exhibits a true sexual propagation, effected by means of the two organs, known as the hornlets (Hörnchen) and spores. Even Vaucher, who first noticed these organs, entertained a suspicion with respect to the nature of the "hornlets," which he declared to be the anthers of the plant, stating that the fertilizing pollen, which, as he thought, filled the entire tube, was discharged through them. With his means of observation he could scarcely have penetrated more deeply into the nature of the process, and it is highly to his credit that he should have advanced so far towards an explanation of it.

This view of Vaucher's with respect to the true nature of the "hornlets," is far nearer the truth than are the assertions of later algologists of the occurrence of a *copulation* of the "hornlet," and the contiguous spore, an assertion which is at once contradicted by attentive consideration of the relative positions of the mouth of the spore and of the "hornlet" before and after impregnation. The notion arose from a supposed analogy between the phenomena of fructification in the *Vaucheriæ* and the formation of the spores in the *Spirogyræ*.

This opinion, however, as well as Karsten's recent unfortunate exposition of the processes said to take place in the "hornlets" and spore-fruit of *Vaucheria* will be found to be untenable from the following description of the act of fructification in that plant.

But the *true process of impregnation* in *Vaucheria* and the development of both kinds of sexual organs—the "hornlet" and the contiguous stunted organ, which is more correctly termed "spore-fruit," [*sporangium*] than "spore," takes place in the following manner. Both organs arise like papillary branches from the tube, and in close proximity; and it is usually the case that the *papilla* destined to become the "hornlet," is formed sooner than that in which the spore originates (Plate III. fig. 1). The two *papillæ* even from the first differ so widely in dimensions, that they can scarcely be confounded. The *papilla* which becomes the "hornlet," soon elongates into a short, cylindrical, slender branch, which, at first, rises perpendicularly from the tube, then curves downwards until it comes in contact with the tube, often forming a second or a third curve, and in this way always represents a more or less stunted branch which frequently exhibits several spiral turns. The *papilla* of the neighbouring "sporangium," usually begins to appear at the time when the "hornlet" is commencing its first turn; but the period at which it arises is very indeterminate, for it sometimes appears much earlier whilst the "hornlet" is still perfectly straight, sometimes much later after it has curved, so as to form two limbs of equal length.

The *papilla* destined to become the *sporangium*, gradually enlarges into a considerable sized, lateral out-growth of the tube, far exceeding the hornlet in width, whilst in length it is barely equal to the straight limb of the latter (fig. 2). This out-growth, which is at first symmetrical, ultimately throws out a beak-like prolongation on the side looking towards the hornlet,—the "rostrate appendage," (*rostrum*) of the *sporangium*, whence the latter acquires its peculiar form, resembling that of a half-developed vegetable ovule (fig. 3). Up to this period the hornlet as well as the *sporangium* are not shut off from the tube from which they spring by any septum; the cavity of the hornlet and that of the *sporangium* consequently remain uninterruptedly continuous with the parent tube, and are filled with similar contents. A great number of elongated chlorophyll granules lodged in an albuminous plasma—never, in this case, starch—and rounded, larger or smaller oil globules, constitute a dense, internal lining in the tube, the *sporangium*, and the hornlet. Between this granular, parietal investment

and the true thick cellulose membrane, is a very thin layer of colourless substance which I have elsewhere described as the "cutaneous layer" (Hautschicht) of the cell-contents.* The *sporangium* is also especially characterized by the circumstance that a considerable number of oil-drops accumulate in it and apparently occupy the whole of its proper cavity.

At this stage of development, a *septum* is suddenly formed at the base of the *sporangium*, which is henceforth an independent cell, completely separated from the parent tube (fig. 4). Even before the *sporangium* has become separated from the parent tube by the septum, there may be noticed in the rostrate elongation directed towards the "hornlet," the gradual accumulation of a colourless fine granular substance, of the same nature as that with which the wall of the parent tube and of the *sporangium* is lined on the inner surface, and which, as I have already stated, has been termed by me the cutaneous layer. This accumulation of the "cutaneous layer" in the fore part of the rostrate process is continued after the formation of the septum between the *sporangium* and tube, and in consequence of its continued increase the remaining contents of the *sporangium*, the oil-drops, chlorophyll, and plasma are by degrees pushed towards the back and base of the *sporangium* (fig. 4). Whilst these phenomena are being manifested in the *sporangium*, the "hornlet" also undergoes very remarkable changes. In its apex, which, so long as the hornlet continues to grow, presents the same conditions as the summits of the growing branches of *Vaucheria*, the contents, owing to the disappearance of the chlorophyll, have become almost completely colourless, except that occasionally a few chlorophyll granules remain; sometimes more sometimes less. Thus the point of the "hornlet," like that of the *sporangium*, appears at this time to be filled with a colourless substance, but which is *not* constituted by an accumulation of the "cutaneous layer" at this point, but manifestly arises from a molecular change associated with an alteration of form and colour in the contents previously existing at the apex. This difference in the mode of formation of the colourless substance, occupying the apices of the horn and of the *sporangium*, should be carefully borne in mind; it is very essentially connected with the different morphological destination of the two substances. So soon as the contents of the point of the "hornlet" have become colourless in the mode just described, they appear to be constituted of a very fine-grained granulose

* A notice of the Author's 'Researches on the Structure and Formation of the Vegetable Cell,' will appear in the next Number of the 'Quarterly Journal of Microscopical Science.'

mucous substance, of whose constitution, however, no clear insight can be obtained. Now, so soon as the transformation of the contents has taken place, the apex of the hornlet, so far as it is colourless, is suddenly parted from the lower, green portion by a septum, and is thus transformed into an independent cell, having no communication with the parent tube, and the basal part of the hornlet. In this case the septum is not formed as in the *sporangium*, at the base of the process, but in the middle. But the point at which the septum is formed, in the "hornlet," is not very determinate; the portion thus cut off from the rest being sometimes larger sometimes smaller.

After the formation of the *septum* in the "hornlet," the colourless mucus in its apex gradually assumes a more determinate form, and at this time a large number of minute, perfectly colourless, rod-like bodies may be readily perceived crowded together irregularly, and which being still here and there surrounded by the amorphous mucus are, as it were, imbedded in it. Close observation also will disclose an indistinct movement exhibited even thus early by some of the little rods, and from which their destination may be anticipated.

This perfecting of the "hornlet" coincides in time with that stage of development of the *sporangium*, at which the accumulation of the "cutaneous layer" in the anterior part of the rostrate process has attained to its greatest extent; and this condition of the *sporangium* and of the hornlet immediately precedes the act of impregnation.

This is effected in the following manner: the pressure within the *sporangium* upon its walls, and especially in the direction of the *rostrum*, becomes greater and greater in consequence of the continued increase of the "cutaneous layer" in the forepart of the *rostrum*, until ultimately the membrane is ruptured exactly at the point of the *rostrum*, and allows a portion of the "cutaneous layer" to escape (fig. 6). The detachment of the extruded portion is attended with all the appearances which accompany the slow separation of a mucous substance into two portions, and which in the present case show in the clearest manner the non-existence of any membrane around the escaped portion of contents. This portion then assumes the character of a drop of mucus, which remains lying near the opening of the *sporangium*, and without undergoing any organization perishes, after exhibiting the various phenomena due to the absorption of water and disintegration (figs. 7 and 8). The accumulation of the "cutaneous layer" in the interior of the *sporangium*, in the anterior part of the

rostrum, and the escape of a portion of it, are merely the mechanism by which the opening is produced in the *sporangium* destined for the admission of the spermatozoids. Immediately after the formation of the opening in the *sporangium*, and in remarkable coincidence with the escape of the "cutaneous layer" through the *rostrum*, the "hornlet" opens at the apex and pours out its contents (fig. 5). Innumerable, excessively minute, rod-like corpuscles, most of them already nearly isolated, though many at the moment of the opening of the "hornlet" still imbedded in the mucus, escape at once though the orifice. Those already isolated exhibit an extraordinarily rapid movement in all directions, and those imbedded in the mucus do not become detached till afterwards, when they follow the others with equal rapidity. The field of view is soon covered with mobile corpuscles. In great number (20, 30, or more) they enter the neighbouring orifice of the *sporangium*, which they fill almost entirely (fig. 9), penetrating through the portion of the cutaneous layer remaining in the *sporangium*, which, though obviously without any definite membranous boundary, owing to its viscous, mucous consistence, offers a solid resistance to their further penetration into the *sporangium*. The corpuscles continue thus to struggle forwards into the "cutaneous layer" for more than half an hour; bounding against its outer surface they retreat, again push forwards, again retreat, and so on in an uninterrupted succession of assaults and retreats—wonderful spectacle for the observer! After this commotion has lasted some time an abrupt boundary-line suddenly appears in the outer aspect of the "cutaneous layer" (fig. 10), the first indication of a tunic forming around the contents of the *sporangium*, which were before bare. From this moment the mobile corpuscles are separated from the "cutaneous layer" by a membrane which effectually prevents their further action upon the contents. They continue, it is true, to move, to and fro, and in the roseate process, and this motion often lasts for hours together, but at last they perish in the *rostrum* itself, their motion becoming gradually slower and slower and finally ceasing. Even after the lapse of several hours, and when the act of impregnation has long been performed, the quiescent, dead corpuscles may be seen in the *rostrum*, lying on the front of the spore in the interior of the *sporangium*, until at last they are completely dissolved and all vestige of them disappears. The portion of the "cutaneous layer," remaining in front of the green contents of the *sporangium*, constitutes a thick stratum of a colourless and transparent substance immediately within the orifice in the *sporangium*,

and consequently the penetration of the mobile corpuscles, the *spermatozoids of the Vaucheria*, into the opening, and their continued efforts, as it were, to force themselves into the "cutaneous layer," may be observed with the utmost distinctness and precision. In several instances also, after the spermatozoids had already been for some time within the *sporangium*, I have very distinctly noticed the sudden appearance of a larger, colourless corpuscle at the extreme border of, but yet *within*, the cutaneous layer (fig. 10), and of which previously not a vestige was perceptible. Its sudden appearance *after* the impregnation, its superficial position in the "cutaneous layer," its consistence and aspect, allow scarcely any doubt to be entertained that this corpuscle arises from one of the spermatozoids. I shall subsequently describe a nearly similar thing attending the act of impregnation in the *Fucaceæ*, and will here merely advert to the remarkable circumstance that the act of impregnation does not take place between a perfectly-formed cell and one or more spermatozoids; but that the action of the spermatozoids is exerted upon the, as yet, unorganized contents of the *sporangium*, which do not become a cell surrounded with a membrane until after the act of impregnation has taken place—the true embryonic cell of the plant.

With respect to the *structure of the spermatozoids of Vaucheria*, I shall here merely remark that when in the mobile condition they present the appearance of elongated slender rods about 1-180‴ in size; when killed by means of iodine, whilst in this state, I have never been able to perceive any further structure in them. Whilst those spermatozoids which have ultimately ceased to move after long-continued struggling, but without having entered the opening of the *sporangium*, appear, very distinctly, like minute clear vesicles, also about 1-180‴ in size, exhibit a distinct opaque, *not* brown point, and, as I have seen with the utmost clearness, two cilia of unequal length. Their movement is obviously more like that of the corpuscles of which the contents of the *antheridia* in *Fucus* are composed, than that of zoospores.

I have stated that the portion of the cutaneous layer left in the *sporangium* after its bursting, and after the entrance of the spermatozoids, together with the remaining contents of the *sporangium*, are surrounded with a membrane, and become a cell which completely fills the *sporangium*—the embryonic cell of the plant.

The *formation of this membrane* of the embryonic cell of *Vaucheria* is one of the most convincing instances in favour of my views respecting the origin of the cell-wall, in an im-

mediate transformation of the "cutaneous layer" (of the so-termed "primordial utricle"). The separation of a portion of the "cutaneous layer," as above described, renders it certain that, at the time when the *rostrum* of the *sporangium* is ruptured, the contents of the latter are not surrounded by any proper membrane: but it is also obvious that the cutaneous layer, which after the escape of a portion of it through the opening still surrounds the green contents of the *sporangium*, and is accumulated in a particularly thick stratum over that part of the contents which correspond with the opening, diminishes considerably in thickness when the formation of the membrane ensuing upon the impregnation takes place; and this diminution in thickness goes on in proportion as the membrane in question *increases* in thickness (figs. 10, 11, 12, 13). In this case the transformation of the cutaneous layer into the membrane may almost be witnessed. This membrane gradually increases to a considerable thickness; at a later period it appears to be formed of numerous thin laminæ, and it applies itself to all parts of the open tunic of the *sporangium* (fig. 14). After the completion of the coat of the true spore, scarcely a trace of the previously well-developed cutaneous layer remains; an excessively thin parietal lining constituted of it alone remaining. The green contents, which had been forced back by the accumulation of the cutaneous layer, in the mean while again spread themselves uniformly throughout the perfect spore, and form as in all cells a thick, internal parietal coating.

The true spore thus formed by the impregnation represents, consequently, a large cell occupying the whole of the *sporangium*, whose membrane, formed probably *in consequence* of and certainly *after* the impregnation, appears to be laminated. It is surrounded on all sides by the persistent tunic of the *sporangium*, which is open in front and prolonged into the rostrum.

In this condition the spore remains for some time longer, without being thrown off from the parent tube on which it was produced: but the colour of its contents, which was at first green, gradually becomes paler and paler; the spore is at last rendered quite colourless, and presents in its interior only one or more largish dark-brown bodies (fig. 14, 16). When it has lost all its colour it is detached from the parent tube, in consequence of the decay of the membrane of the *sporangium* enclosing it (fig. 17). After some time (in my experiments, after about three months) the spore, which is readily recognizable by the red-brown *nuclei* in its interior, suddenly resumes its green colour (fig. 18), and immediately

thereupon grows into a young *Vaucheria*, exactly resembling the parent plant (fig. 19, 20). Close observation shows that the innermost layer, elongating, breaks through the thick outer membrane, and becomes the young tube, exactly in the same way as I have described the process of development in the germinating spore of *Spirogyra*.

The observation of the *germination* of this spore, however, completes the proof that the cell produced in consequence of the action of the spermatozoids is the true propagative cell of *Vaucheria* arising from a sexual act.

(*To be continued.*)

On SPHÆROZOUM, Meyen. (THALASSICOLLA, Huxley.) NOCTILUCA, *and the* POLYCYSTINÆ. By Prof. MÜLLER. ('*Report of Berlin Academy*,' *April* 19, 1855.)

IN the 'Annals of Nat. Hist.,' 2 ser., vol. 8, p. 433, Mr. Huxley describes what he regarded as a new genus of zoophytes, under the name of *Thalassicolla*. This production, whether animal or vegetable, is found in transparent, colourless, gelatinous masses of very various forms and size; showing no evidence of contractility nor any power of locomotion.

Of such bodies Mr. Huxley notices two very distinct kinds—the one, consisting of oval or constricted, and many spherical masses, is distinguished to the naked eye by possessing numerous darker dots scattered about in its substance; whilst the other is always spherical, has no dots, but presents a very dark, blackish centre, the periphery being more or less clear.

For the former kind Mr. Huxley adopted the provisional name of *T. punctata*, and for the latter that of *T. nucleata*, but without prejudging the question as to the existence of specific distinctions.

These creatures, which are described as consisting fundamentally of a mass of cells united by jelly, "like an animal Palmella," are placed by Mr. Huxley with the Protozoa, and regarded by him as belonging to the same great division as the *Sponges*, *Foraminifera*, *Infusoriæ*, and *Gregarinida*,—unicellular animals. Of the two species, *T. punctata* and *T. nucleata*, the former appears to present several varieties, and the latter seems to approach very closely in its nature to *Noctiluca*.

In the Reports of the Berlin Academy for April 19, 1855, is a paper by Prof. Müller upon *Sphærozoum* and *Thalassi-*