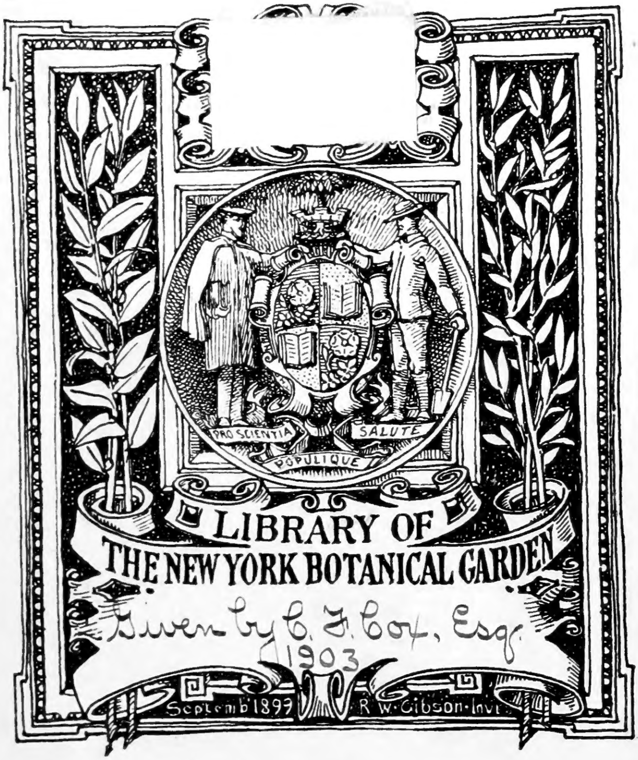
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JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY;

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS,

AND A SUMMARY OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY
(principally Invertebrata and Cryptogamia),
MICROSCOPY, &c.

Edited by
FRANK CRISP, LL.B., B.A.,
One of the Secretaries of the Society
and a Vice-President and Treasurer of the Linnean Society of London;

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE AND

A. W. BENNETT, M.A., B.Sc.,
Lecturer on Botany at St. Thomas's Hospital,

F. JEFFREY BELL, M.A.,
Professor of Comparative Anatomy in King's College,

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FELLOWS OF THE SOCIETY.

Ser. II.—VOL. I. PART 1.

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1881.

PREFACE.

THERE is little to add to what was stated in the Preface to Vol. III., the plan there explained having been followed in the present volume.

The section of the 'Summary of Current Researches,' which deals with Microscopy (properly so called), is now, it is believed, as complete as it can be usefully made. The Editors have every wish that the sections of Zoology and Botany should be equally complete, but the possibility of giving practical effect to this desire is unfortunately limited by considerations with which it is out of their power to deal.

It should be observed that the 'Summary' as well as the 'Transactions' includes original communications from Fellows and others.

So many requests have been made that the Microscopical Bibliography should be continued, that it is intended to give in future volumes a list of all the Books and Papers from time to time published relating to Microscopy, divided in the same way as the corresponding part of the 'Summary,' viz. into (α) Instruments and Accessories, and (β) Collecting, Mounting, and Examining Objects. Where it is not intended to publish an abstract of a paper included in the Bibliography, a brief note of the purport of the paper will be added when this is not sufficiently indicated by the title alone. The new list will commence at the point where the old one left off, so as to cover the intervening period.

The Index has been continued on the same extended basis as hitherto, and a List of Authors has been added. The classified portion of the Contents now includes cross references to any notes which may relate to two subjects, and also the titles of the papers published in the 'Transactions,' and those of the principal notes in the 'Proceedings' which do not appear elsewhere in the Journal.

It may be repeated here that it is no part of the object of the 'Summary' to criticise the views of the authors of the papers abstracted, its main object being to bring to the notice of the Fellows the contents of the principal papers from time to time published, and which are scattered through a vast and ever-increasing mass of periodical literature. The sources from which the abstracts are taken are in all cases noted, so that reference can readily be made to the originals.

FRANK CRISP.

THE

Royal Microscopical Society.

(Founded in 1839. Incorporated by Royal Charter in 1866.)

The Society was established for the communication and discussion of observations and discoveries (1) tending to improvements in the construction and mode of application of the Microscope, or (2) relating to Biological or other subjects of Microscopical Research.

It consists of Ordinary, Honorary, and Ex-officio Fellows.

Ordinary Fellows are elected on a Certificate of Recommendation signed by three Fellows, stating the names, residence, description, &c., of the Candidate, of whom one of the proposers must have personal knowledge. The Certificate is read at a Monthly Meeting, and the Candidate balloted for at the succeeding Meeting.

The Annual Subscription is £2 2*s*., payable in advance on election, and subsequently on 1st January annually, with an Entrance Fee of £2 2*s*. Future payments of the former may be compounded for at any time for £31 10*s*. Fellows elected at a meeting subsequent to that in June are only called upon for one-half of the year's subscription, and Fellows absent from the United Kingdom for a year, or permanently residing abroad, are exempt from one-half the subscription during absence.

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The Council, in whom the management of the affairs of the Society is vested, is elected annually, and is composed of the President, four Vice-Presidents, Treasurer, two Secretaries, and twelve other Fellows.

The Meetings are held on the second Wednesday in each month, from October to June, in the Society's Library at King's College, Strand, W.C. (commencing at 8 P.M.). Visitors are admitted by the introduction of Fellows.

In each Session two additional evenings are devoted to the exhibition of Instruments, Apparatus, and Objects of novelty or interest relating to the Microscope or the subjects of Microscopical Research.

The Journal, containing the Transactions and Proceedings of the Society, with a Summary of Current Researches relating to Zoology and Botany (principally Invertebrata and Cryptogamia), Microscopy, &c., is published bi-monthly, and is forwarded *gratis* to all Ordinary and Ex-officio Fellows residing in countries within the Postal Union.

The Library, with the Instruments, Apparatus, and Cabinet of Objects, is open for the use of Fellows on Mondays, Tuesdays, Thursdays, and Fridays, from 11 A.M. to 4 P.M., and on Wednesdays from 7 to 10 P.M. It is closed during August.

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LIST OF AUTHORS.*

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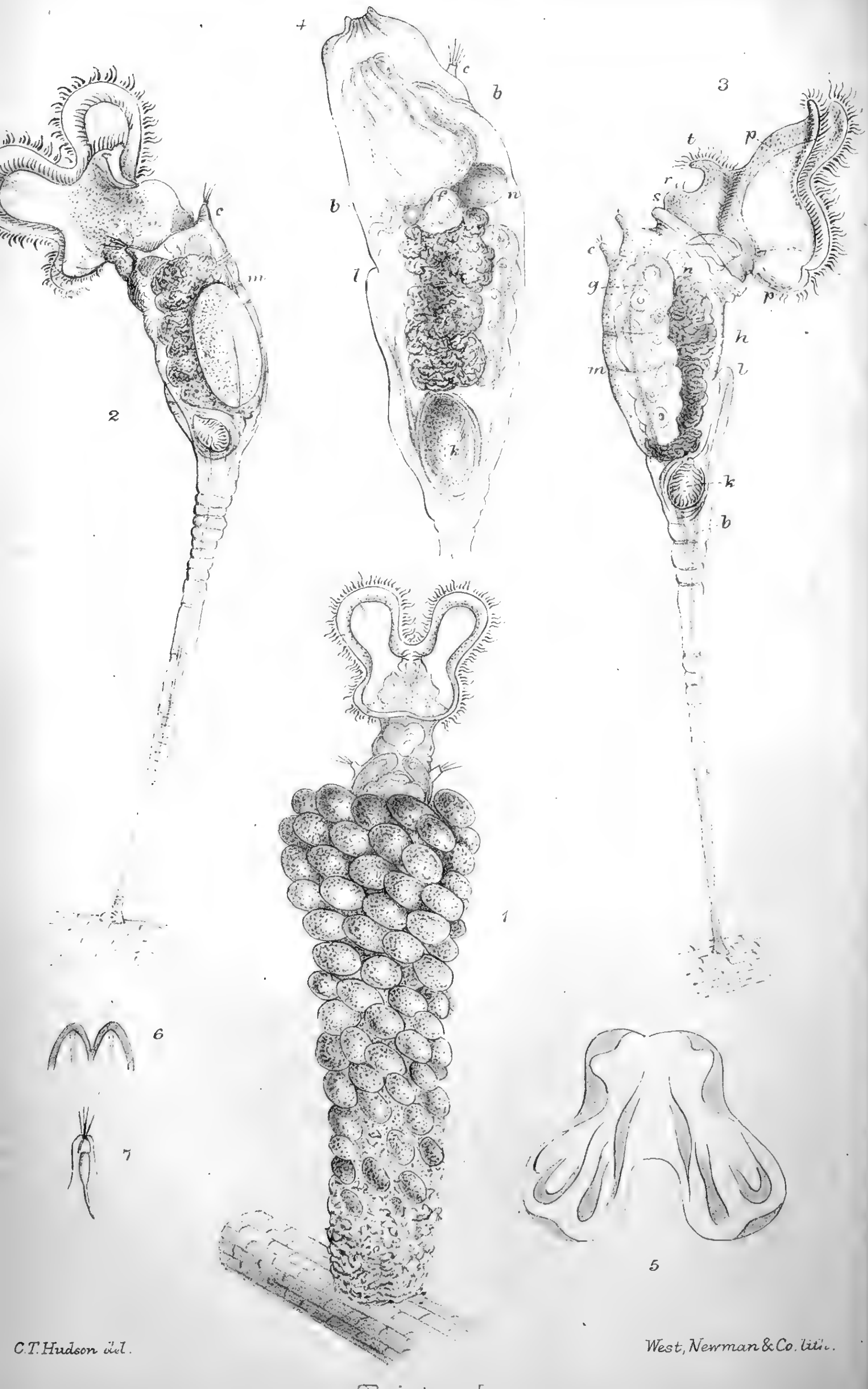

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Œcistes Janus.

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Floscularia trifolium.

JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY.

FEBRUARY 1881.

TRANSACTIONS OF THE SOCIETY.

I.—*On Œcistes Janus and Floscularia trifolium, two new species of Rotifers.* By C. T. HUDSON, M.A., LL.D., F.R.M.S.

(*Read* 8*th December*, 1880.)

PLATES I. AND II.

Œcistes Janus.

THE new tube-making rotifer, *Œcistes Janus,* was discovered by Mr. J. Hood, of Dundee, in Loch Lundie, in September of this year (1880). It appears to prefer deep water as its habitat, and is found in the greatest number and best condition, Mr. Hood tells me, at a depth varying from 6 to 10 feet. At first sight it was naturally supposed to be a specimen of *Œ. pilula,* which, so far as its tube is concerned, it very closely resembles; but the unfolding of its trochal disk at once showed Mr. Hood that he had secured a prize.

Œ. Janus is a most striking addition to the Melicertidæ, for it

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EXPLANATION OF PLATES I. AND II.

Œcistes Janus.

FIG. 1.—Female in tube, antoral view, expanded.
„ 2. „ out of tube, nearly oral view, expanded.
„ 3. „ „ side view, expanded.
„ 4. „ „ „ closed.
„ 5.—Trochal disk; showing its thickenings.
„ 6.—Extremity of chin.
„ 7.—An antenna.

Floscularia trifolium.

FIG. 1.—Three females, from different points of view.
„ 2.—Side view of the body.
„ 3.—Back view of trochal disk; showing the two rows of setæ down one side of a lobe.

In all the figures:—*a*, horseshoe row of small cilia; *b*, longitudinal muscles; *c*, antenna; *d*, crop; *e*, tube from mouth into crop; *f*, mastax: *g*, ovary; *h*, stomach; *k*, its lower division; *l*, vent; *m*, transverse muscle; *n*, gastric gland; *o*, ganglion; *p*, thickening of trochal disk; *r*, curved bristles; *s*, knob-covering gland; *t*, ciliated chin.

forms a connecting link between the two genera *Œcistes* and *Melicerta;* the upper half of its trochal disk being that of the latter, while the lower half is that of the former. Seen from the oral surface as in Fig. 2, no one would suppose it to be other than a true *Melicerta,* living in a tube of fæcal pellets; but viewed from the antoral surface as in Plate I., Fig. 1, its relationship to *Œcistes* is at once apparent, for though the upper half of the trochal disk is deeply cleft into two lobes (just as in *Melicerta*), the lower half is almost a single lobe, there being the slightest possible hint of a notch at the lowest point.

It would seem then, at first, as if this new species ought to decide the point as to whether the five genera, *Œcistes, Limnias, Tubicolaria, Melicerta,* and *Cephalosiphon* should be reduced to one, as Gosse proposed nearly twenty years ago; for as the form of the trochal disk is one of the main differences between these genera, the existence of a species possessing half the trochal disk of one genus and half of another, shows, one would say, that the separation of the genera cannot easily be maintained. Gosse thought that the differences of the trochal disks, &c., were not sufficient to warrant the formation of five genera of such similar creatures, especially when, as was the case when he wrote, each genus contained but *one* species.

At the date of Gosse's paper, the five genera were represented only by *Œcistes crystallinus, Limnias ceratophylli, Tubicolaria naias, Melicerta ringens, Cephalosiphon Limnias;* but the list now is extended as follows: *Œcistes crystallinus, Œ. longicornis* (H. Davis, 1857), *Œ. intermedius* (H. Davis, 1867), *Œ. pilula* (J. G. Tatem, 1868), *Œ. umbella* (F. Oxley, 1879), *Œ. Janus* (J. Hood, 1880); *Limnias ceratophylli, L. annulatus* (Bailey); *Melicerta ringens, M. tubicolaria* (= *Tubicolaria naias* = *M. Tyro*); *Cephalosiphon Limnias.*

The only genus with a single species now is the very well-marked one *Cephalosiphon,* and Mr. Hood tells me that he has seen a new species of this genus on the weed from Loch Lundie.

While admitting, then, the close connection of these genera, I still think it would be inexpedient to reduce them all to one. With the single exception of *Œ. Janus* (and in its case only from one point of view), the old genera are at once recognizable by their trochal disks, and generally by their tubes.

The new rotifer is, I think, an *Œcistes* rather than a *Melicerta.* It is true that Mr. Cubitt named Mr. Tatem's very similar rotifer *Melicerta pilula;* but that was because he was avowedly adopting Mr. Gosse's suggestion of reducing the five genera to one: *M. pilula* is a true *Œcistes.*

No one who has watched *Œ. Janus* open its trochal disk could mistake it for a *Melicerta.* Like *Œ. umbella,* and indeed like all members of this genus, the disk is in many places very thin and transparent, while across it run stout thickenings, Fig. 5, between which the thinner portions are folded when the disk is closed, and which serve both to open the disk and to keep it extended in various degrees—acting indeed somewhat like the ribs of an umbrella. These stout ribs protrude in a squarish bundle when the creature begins to open its disk, and give the head a most characteristic outline, which I have drawn in the case of *Œ. umbella* in this Journal, vol. ii. (1879), p. 1. The contrast between the thinner and thicker portions of the disk is well seen in a side view, as in Fig. 3, especially with dark field illumination, under which the ribs, *p*, *p*, stand out distinctly, while the substance of the disk between becomes nearly invisible, its edge being marked out by the two parallel curves of cilia.

Œ. Janus is a large rotifer, and the cilia of its trochal disk are unusually fine, while the groove that lies between the primary and secondary rows of cilia, is both broad and deep. Should the motion of the larger cilia be checked by contact with the side of the cell in which it has been placed, they may be easily counted, while their whip-like mode of action becomes plainly visible. Even in the case of the finer secondary row, individual cilia may be occasionally seen, while the combined effect of the whole does not admit of question. As in all the *Melicertidæ*, the action of the larger cilia draws a current of water at right angles to the trochal disk, and atoms floating in the current impinge on the disk, slide over its surface, and then slip over the edge between the bases of the larger cilia into the groove between the two rows, along which they are driven by the smaller cilia to the mouth. Above the mouth the groove ends in two ciliated knobs, which are constantly approaching to or receding from each other as they regulate the supply; and beneath them again, but above the mastax, a pair of lips, if I may use the term, are often seen to spring up to seize or reject some morsel. The greater part of the current from the groove passes beyond the mouth along a ciliated trough, ending in what Mr. Gosse terms the "chin." In *Œ. Janus* this "chin," Fig. 6, is peculiar in shape, being divided into two peaks. Below the divided chin is a pair of thin walls, looking exactly like the supports of a bracket—the chin being the bracket itself. The chin above, the walls on each side, and the concave surface of the body which they enclose, together make something very like Melicerta's ciliated cup; but I have not been able to detect any cilia, while in *Œ. pilula* there is a distinct ciliated tract lying beneath the chin. Below this cup-like spot is a knob, Figs. 2, 3, which is rather more prominent than in some of the tube-makers, and just above I could now and then see two or more curved bristles which are peculiar to *Œ. Janus*.

Mr. Hood had not only noticed them, but he had the good fortune, which I have not had, to see how they were used, and to watch the rotifer building his tube. As is the case in all the tube-makers, there is an inner gelatinous tube generally of considerable thickness, and this is secreted by the rotifer itself. The outer case is formed by fæcal pellets, which are laid one by one in spiral curves round the inner one; a mode of fortifying the tube, which is adopted also by *Œ. pilula.* The pellets adhere pretty firmly together, and must make a very efficient protection for the timid and delicate creature within, for I watched an annelid doing its best to pull a tube to pieces, and though the worm nibbled at the pellets, and roughly pushed the tube backwards and forwards for a considerable time, it seemed quite baffled by its toughness and elasticity, and went away at last leaving the rotifer, who was hauled down close at the bottom of the tube, unharmed within.

In building its tube, Mr. Hood says that "the animal does not appropriate every fæcal pellet as it is voided, but only one now and then as occasion requires. It generally stoops to emit a pellet, and having done so allows the pellet to float away, but when it means to use it for the tube, it takes an erect position and seizes the pellet by the bristles, Fig. 3, *r*, above the knob, and retires with it a short distance into its tube; it then stoops its head and places the pellet on the edge of the tube, pushing it off the bristles by the help of the knob."

Mr. Hood also informs me that he has seen the male, and that it much resembles that of *Melicerta tubicolaria.* Of the young female, he says that it takes four days after it is hatched to acquire its perfect form, and ten days to acquire its full growth. This seems a slow rate of growth for so minute a creature, but some of the rotifers take longer still; for instance, I once had the opportunity of watching the growth of a young *Cephalosiphon Limnias*, and it took quite twelve days to attain to half the size of the full-grown animal.

Floscularia trifolium.

Mr. Hood has also discovered another striking novelty in Loch Lundie, viz. a very large Floscule, having only three lobes, and of great transparency and beauty; indeed, as its discoverer well says, "the belle of the rotifers." At first sight I thought it was *F. trilobata*, described by Dr. Collins in 'Science-Gossip,' January 1872; but the differences between Dr. Collins' description and Mr. Hood's rotifer are great.

F. trilobata is said to have much shorter setæ than other Floscules have, to have its dorsal lobe generally much larger than the other two, and to have a very long cloaca running up the side of the body opposite to the dorsal lobe, and ending between the two smaller lobes on the level of their basis; and although said to be one of the "largest of the Floscules," its "total length" is given at $\frac{1}{40}$ of an inch.

Now *F. trifolium* has setæ of about the usual length, its dorsal lobe is only slightly larger than the other two, its total length is $\frac{1}{15}$ of an inch, and its cloaca and vent (as in all other Floscules I am acquainted with) are on the side of the dorsal lobe. It is possible that the two animals are the same, for there must, I think, be at least one grave error in Dr. Collins' description, viz. that as to the cloaca; but as I have to choose between the possible error of describing two different rotifers under the same name, or the same rotifer under two different names, I have thought the best course to be to call Mr. Hood's Floscule *trifolium*, and give *trilobata* a chance of putting in an appearance on some other occasion.

Dr. Collins also states that *F. trilobata* has its setæ arranged in an unusual manner, "being placed between their lobes as well as on their summits, forming a kind of unbroken fringe along the entire margin of the disk."

Now in *F. trifolium* the setæ are also set along the entire margin of the disk, but the arrangement is not novel, for it is exactly the same in *F. campanulata*. The fact is that the setæ in these Floscules are so placed that it is impossible to see all those on one lobe at once. No three of them are in the same plane. While those on the top of the lobe point forwards from the body, those at the bottom of the lobe actually point backwards towards the foot, and as they pass down the margin of the lobe from its highest to its lowest point, their inclination constantly changes so as gradually to alter from the first of these directions to the latter. The consequence is that, look at the lobe from what point of view you will, many of the setæ must be invisible, as they are actually pointing right up the Microscope. Then again, although really very long, they often look short from their curvature taking their upper portions right out of focus. *F. trifolium* has, however, a second smaller row of setæ, much shorter, and running round each lobe parallel to the larger fringe, and curved inwards. This arrangement is shown in Plate II., Fig. 3, and is, I believe, peculiar; at least I have never noticed it in any other Floscule. If any small floating atom attempts to escape from the meshes of the living net formed by the interlacing setæ, a swift wave of motion is seen to run all along the smaller row, and it is often caught and thrown back into the hollow globe formed by the three lobes.

The first thing that strikes the observer on watching the furled head protrude from its tube is the great size of the rotifer, and the curiously shrivelled appearance that the lobes of the trochal disk have as they emerge from the opening head. In a few seconds the lobes gently expand, the many folds and creases slowly disappear, till at last the eye is gratified with the sight of a lovely diaphanous tulip, the rim of which is fringed all round with delicate and motionless hairs.

Neither pen nor pencil can do justice to the exquisite grace of this beautiful creature. From every point of view the flowing curves of the trochal disk are charming, and its great transparency permits of the whole outline of the rim being seen at once. One of the lobes (that usually termed the dorsal one) is rather larger than the others, and it is slightly curved over the mouth; across each lobe run delicate muscular threads for furling it. The expansion of the lobes is doubtless produced by the transverse muscles of the body, which, by compressing it, force fluid upwards between the two membranes of which the lobes are composed. This can be readily seen in *F. campanulata,* in which the fluid carries along with it numbers of granules, whose rush upwards to the lobes, as the Floscule expands, is easily visible under dark field illumination.

It was for a long time a moot point how the vortex was caused which, setting down between the lobes, drew its prey to the Floscule's mouth; and at last it was made out that a horseshoe-shaped row of very fine cilia (Figs. 1 and 2, *a*) lay at the bottom of the lobes where they join the neck. If *F. trifolium* had been a common rotifer, there would have been no difficulty about the matter, for this row of small cilia can be easily seen in almost any position, owing to the animal's great size and transparency. It is unnecessary to describe in detail its other organs, as so far as I have observed they are in no respect different from those of the other Floscules.

I will conclude, therefore, by hoping that Mr. Hood will not leave Loch Lundie unvisited next summer, and that the skill and perseverance which he showed when he fished up *Œ. Janus* from a depth of ten feet, will often be turned to good account in that admirable hunting-ground.

SUMMARY

OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(*principally Invertebrata and Cryptogamia*),

MICROSCOPY, &c.,

INCLUDING ORIGINAL COMMUNICATIONS FROM FELLOWS AND OTHERS.[*]

ZOOLOGY.

A. GENERAL, including Embryology and Histology of the Vertebrata.

Rhythmical Character of Segmentation.[†]—Mr. W. K. Brooks directs attention in a brief note to the fact that a number of observers have lately observed this phenomenon. Dr. Clarke has seen it in the amphibian *Amblystoma*, Mr. Brooks in the egg of an unknown fish, and Wilson in Polychæta and Oligochæta; so too it has been seen in the Arthropod *Leucifer*. The ova of these forms do not by any means exhibit the same method of segmentation. Mr. Brooks is inclined to find an explanation in the alternation of rest with activity, and to ascribe the change in shape during the resting periods to the physical properties of the egg (its elasticity tending to render it spherical). "In most eggs the yolk is not sufficiently elastic to allow any great change of form, but careful time-records show that the process of segmentation is rhythmical." It is to be hoped that the attention of observers will be directed to this phenomenon.

Secondary Yolk in the Germinal Vesicle of Mammalia.[‡]—Prof. A. Rauber has a note on this subject, induced by his discovery in the yolk-sac of the embryos of young guinea-pigs, at the time of the first circulation, of a number of formed elements. Inspection of sections led to the view that they arose from the germinal vesicle. The spheres of the yolk-sac agree in all essential points with the elements of the yellow yolk (as e. g. of birds). It seems, therefore, to be certain that, like them, they are used for the nourishment of the embryo. Some of this yolk, at any rate, owes its origin to the epithelium of the yolk-sac.

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[*] The Society are not to be considered as responsible for the views of the authors of the papers referred to, nor for the manner in which those views may be expressed, the object of this part of the Journal being to present a summary of the papers *as actually published*, so as to provide the Fellows with a guide to the additions made from time to time to the Library. Objections and corrections should therefore, for the most part, be addressed to the authors. (The Society are not intended to be denoted by the editorial "we.")

[†] Amer. Journ. Sci., xx. (1880) p. 293.

[‡] Zool. Anzeig., iii. (1880) pp. 591–4.

Notochord of Mammals.[*]—Prof. H. Leboucq has examined embryos of man, ruminants (lambs and calves), rodents (rats, mice, guinea-pigs, but especially rabbits), and the mole, afterwards comparing these with a few observations on the chick, for the purpose of studying the retrograde metamorphosis of the notochord among the higher vertebrates. The results of his predecessors are very briefly noted. He strongly recommends the method of decalcification by picric or nitric acid, indicated by Busch,[†] to all who have to deal with osseous pieces of large extent.

The mammalian notochord exhibits at least three phases of retrogression. During the first it is still continuous, its fusiform intervertebral enlargements alternating with much narrower vertebral portions. The former consist of two kinds of nucleated cells, central and peripheral. The central cells are loosely united, with intervening lacunæ. These lacunæ cause the appearance of the lumen noted by His.[‡] The peripheral cells are closely approximated, as in an epithelium. Cells of one kind only make up the vertebral portions; they are like the central cells of the intervertebræ. The skeletogenous tissue nearest the chorda shows also a certain alternation of structure, and may be said to constitute a series of sheaths for its vertebral (but not for its intervertebral) portions. The chorda displayed the structure just mentioned in a human embryo (of the eighth week) 2·5 cm., and in one embryo of the cow 3 cm. long. In a younger embryo of the cow, from 1 to 2 cm., Dursy found the intervertebral constituents of the chord alternating with fusiform vertebral enlargements, and directed attention to the curiously changed proportions which the two kinds of segments afterwards present.

In the second stage the chorda is broken up. It now consists of distinct intervertebral and vertebral segments. These last are best seen in sections across the bodies of the young vertebræ. Each appears as a nucleated reticulum with very little protoplasm, and is surrounded by a perichordal sheath finely striated longitudinally. Outside this is a layer of cartilaginous cells; next comes the ossifying tissue. Towards either end of the newly forming bone, as we find by making a number of transverse sections, the chord vanishes; but the radiating disposition of the cartilaginous cells remains to indicate the fact of its disappearance. The more conspicuous intervertebral segments are now further vacuolated, shortened, and stretched in diameter. This increase is mainly due to the encroachment and blending of the perichordal tissue. A simultaneous formation of giant (multinucleated) cells takes place. By this invasion and dissociation, already begun in the preceding phase, the segments lose their fusiform figure, becoming irregular in shape while they increase in volume. The hypothesis of Löwe, admitted by Kölliker, that the intervertebral segments withdraw by a sort of attraction the rest of the chordal substance into themselves—is inconsistent with the presence of vertebral segments during this stage.

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[*] Arch. de Biol., i. (1880) pp. 718–736 (1 pl.).

[†] Arch. Mikr. Anat., xiv. p. 480.

[‡] The author's reference should be to p. 48, not to p. 68, of the work of His.

The third stage is marked by the complete absence of all traces of the vertebral segments; these, however, gradually disappear. The intervertebral segments become still more completely dissociated, in a manner for the right understanding of which figures are necessary. In the human fœtus after birth indications of these segments may yet be seen. The "pulpy nucleus" of each segment is chiefly formed by the perichordal tissue.

A comparison of mammalian embryos with those of the chick demonstrates modifications of detail, in accordance with the particular forms eventually assumed by the articulating ends of the vertebral bodies.

Embryology of Selachians.*—Well-preserved embryos of *Acanthias* from Heligoland were examined by Dr. H. Rabl-Rückhard, of the Berlin Museum, with a view to determine (I.) the cephalic ending of the chorda dorsalis, in its relations towards the hypophysis cerebri and the so-called middle trabecula, and (II.) the origin of the pineal gland.

I. Since the publication of Balfour's monograph, Reichert has described the embryo of an *Acanthias* whose notochord he believed could be traced through the cranial floor in front of and below the hypophysis. Dr. Rabl-Rückhard has been fortunate enough to find an embryo of the same stage of development as Reichert's, corresponding to that which Balfour indicates by the letter K. The appearances presented by dorso-ventral sections of the head in this and in older embryos are described and figured. Other figures, chiefly showing transverse sections of various embryos, are given. And there is a dorso-ventral section of an embryo of *Mustelus vulgaris.* From a comparison of several preparations Dr. Rabl-Rückhard concludes that—

(1) At no period of its development has the embryo of *Acanthias* a notochord with its apex projecting beyond that part of the base of the skull which subsequently becomes the dorsum sellæ;

(2) The hypophysis arises immediately in front of the apex of the notochord in the basal portion of that deposit of connective tissue which is termed the middle cranial trabecula;

(3) The summit of this rudiment (Reichert's processus sellæ turcicæ) does not pass into the later sella turcica, but becomes the adventitia of the basilar artery.

On the whole, the author confirms, against Reichert, the previous conclusions of W. Müller, Balfour, and Parker. But though it is certain that the notochord stops short of the hypophysis and lies behind (not beneath) it, this is not irreconcilable with Reichert's other statement (by him injudiciously confounded with his first) that the chorda of young sharks at a certain period of development reaches to the frontal wall (*Stirnwand*). The cephalic flexure shows us that such a state of things is quite possible.

The minute structure of the notochord, as seen in sections, is described with its axial string of large, clear, vesicular cells, forming

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* Morph. Jahrb. (Gegenbaur), vi. (1880) pp. 535–70 (2 pls.).

a single row at its most anterior extremity, invested by a layer of smaller cells which are richer in protoplasm, the whole contained within a structureless envelope (primitive or chordal sheath of Gegenbaur). Beyond this cuticle we encounter successively (*a*) Gegenbaur's skeletogenous sheath, (*b*) its limitans externa, (*c*) the outlying basilar cartilage, and (*d*) the perichondrium. The changes in shape and size which the notochord displays as we proceed from before backwards are of much interest, but could not be profitably explained without the figures.

Dr. Rabl-Rückhard has not traced the actual origin of the hypophysis, but a comparison of his sections confirms the accuracy of Balfour's observations. The early development of this structure in Selachians agrees with its beginning in birds, as since seen by Mihalkowicz and others. The hypophysis may be assumed to occupy the same position in all the Craniata.

As to the middle trabecula of Rathke, neither can this name nor that subsequently proposed for the same part by Reichert be considered appropriate. Posteriorly, it passes continuously into the connective tissue occupying the floor of the vertebral canal and insinuating itself between the surface of the medulla and the cartilaginous investment of the notochord, to constitute at a later stage the membranes of the great nervous centres. The connection between these membranes and the middle trabecula demonstrates that the latter is at first nothing more than a specially developed vascular extension of the pia mater.

II. It is manifestly important to fix the data for exact comparison of the brains of the higher vertebrates with those of the lower. It would be an advantage if these data were beyond the reach of controversy, since young anatomists are puzzled when they find that so high an authority as Gegenbaur has wavered between the interpretation of the fish's brain promulgated by Miklucho-Maclay and the more orthodox (and usual) view which has found its chief modern supporter in Stieda. More recently, the copious and original work of Fritsch, while containing valuable additions of detail, has further involved the whole subject in much perplexity.

The pineal gland, although functionally of no interest, here affords a valuable landmark. By ascertaining its true position, we advance towards the solution of the problem now before us. In all the higher vertebrates, as Stieda insists, it lies dorsally between structures which correspond to the primary first and second cerebral vesicles. But Fritsch asserts that such a position must be ascribed to secondary displacement, and supports this opinion by an appeal to horizontal sections of the brains of the eel and frog. In accordance with these, he maintains that the parts immediately behind the pineal gland in fishes and batrachians belong, not to the middle, but to derivatives from the first primary cerebral vesicle. He thus errs both as to logic and matters of fact. For if the pineal gland really shift in this way, its utility to the morphologist becomes questionable. However, Balfour and Ehlers have demonstrated that in elasmobranch fishes the pineal gland is developed just as among the higher vertebrates. Götte has proved that a like origin obtains in the case of *Bombinator*. The method of vertical sections used by these investigators yields, in the present inquiry, views more trustworthy than that of Fritsch. Also, it is plain that the distal extension of the pineal gland, cursorily noted, may easily mislead as to its proximal origin. Besides indicating these sources of error, Dr. Rabl-Rückhard, by positive observations, confirms the results of Balfour, and leads us to expect further original contributions to our knowledge of the development of the cerebral centres among the other vertebrates.

Tail in the Human Embryo.*—M. His in a paper on this question disputes the assertion that has been made that at a certain stage in its development the human embryo has a true tail, which is afterwards absorbed. As to the definition of a tail, M. His considers that the caudiform or tail-like prolongation is a true tail when, extending beyond the cloaca, it contains a number, greater or less, of supernumerary vertebræ. Without this condition there is merely a caudiform appendage. The author knows of no well-authenticated case of supernumerary vertebræ in the human embryo, and pathological observation he believes to coincide with embryological knowledge in justifying the assertion that in man the normal number of thirty-four vertebræ is never exceeded.

Structure and Life of Cells.†—Professor W. Flemming continues his researches on cells and nuclei, this second Part comprising three sections, with an introduction on terminology, and a short appendix on technical methods.

Almost the whole of the present part is devoted to the nucleus, and especially to a critical study of its changes during division. In its resting state, that stage which is most remote from division, the nucleus consists of (1) an intertrabecular substance, traversed by the (2) intranuclear plexus, with its (3) nodes, (4) nucleoli, and (5) nuclear membrane. These parts bear the following synonyms:—1, intermediate substance (*Zwischensubstanz*); 2, intranuclear structure (Flemming's own translation of *Kerngerüst* or *Kernnetz*) = "framework" of Klein; 3 (*Netzknoten*); 4 (*Kernkörperchen*); 5 (*Kernmembran oder Wand*). Flemming would no longer, as in Part I., resolve the whole nucleus into *Kernsubstanz* and *Kernsaft;* since under the former we should then include the membrane and plexus, together with the nucleoli. But these are of different nature. Again, the *Kernsaft*, as Klein rightly urges, is not liquid. *Kernsubstanz* is better opposed in meaning to *Zellsubstanz*, that is, to the extranuclear protoplasm. That chemical component of the nucleus which is not affected by staining reagents, is now termed *achromatin*, in contrast to *chromatin* (by Flemming hitherto called "stainable nuclear substance"), a word used without prejudice to future researches touching the uniformity of the constituent thus designated

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* Arch. Sci. Phys. et Nat., iv. (1880) pp. 414–6.

† Arch. Mikr. Anat., xviii. (1880) pp. 151–259 (3 pls. and 5 figs.). For a notice of Part I. see this Journal, ii. (1879) p. 137.

in diverse cells. The chromatin is diffused through the whole resting nucleus; though found chiefly in the nucleoli, plexus and membrane, it also exists in the intertrabecular substance. The adjectives *chromatic* and *achromatic* explain themselves. Division of nuclei is *indirect* wherever accompanied by metamorphosis of the nuclear mass into filaments; it is *direct* if there be no such metamorphosis. Both these terms are provisional. Flemming proposes to drop them as superfluous, should it at length be shown that but one (indirect) mode of division occurs. He would extend the expression *karyokinesis*, introduced by Schleicher and adopted by Strasburger, to all movements or changes of position undergone by the nuclear filaments during division. Schleicher accepts this extended meaning. Flemming objects, however, to Schleicher's occasional use of "amœboid" as a synonym for *karyokinetic*. The latter word is preferable, as indicating the mere occurrence, and not also the supposed cause, of the nuclear movements; as to which cause, we cannot say whether it be intrinsic, extrinsic, or mixed. "Amœboid," like "contractile," is rightly applicable to those changes of form whose proximate cause lies in the cell itself. Moreover, the irregularity of amœboid movements strikingly contrasts with the almost isochronous and much more definite transformations of the nuclear filaments. *Nuclear figure*, and not "karyokinetic figure," is Flemming's term for all phases which the nucleus assumes during division. Strasburger, accepting the same phrase, has applied it to the middle stages (spindle or barrel figures) only. The terms *coil* (*Knäuel*, also *Korb* or basket), *star*, and *equatorial plate* indicate the principal phases of division, respectively.

That such definite phases appear and recur with much regularity, although not always manifested in the same distinct manner, among various animal and vegetable cells, is now probable. Such is the thesis maintained by Flemming in his first Section, along with the proposition that indirect division has been proved to be of very general occurrence. Moreover, in appreciating these truths, their physiological no less than their morphological significance must be considered. This being so, we are able to avail ourselves of the ready means of demonstration which the large and more easily examined cells of batrachians (amphibians) present, in comparison with cells whose smaller nuclei need the use of higher powers, and afford, save under unusually favourable circumstances, but occasional glimpses of the phases we seek. The new objects which are here reviewed and figured are chiefly taken from the tegumentary and testicular epithelium of the Salamander; but ten figures are added from plants (endosperm of *Nothoscorodon fragrans* and epidermis of pistil in *Allium odorum*), affording data for a discussion of some of the results of Strasburger, besides a few others from the oral epithelium of the tadpole, the omentum of the kitten, and the ova of a sea-urchin (these last after preparations by H. Fol). In the same connection Flemming notices those writers who support or partly contradict his views, and cites several in addition to those mentioned in his former papers.*

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* Part I., and in Virchow's Arch., lxxvii., March 1879.

A supplement to the first Section sustains the observations of Treub, who in multinucleate vegetable cells saw all the nuclei dividing at the same time. Flemming further holds that a like simultaneity extends to the several phases of division. Cells from the testis and binucleate cells from the gills of *Salamandra* showed this phenomenon.

Having advocated the approximate universality of indirect division, and the normal repetition of correspondingly similar phases, Flemming in his second section gives a revised account of (1) the successive phases which appear in well-observed cases, (2) the transitions from one to the other, (3) the subsidiary phenomena which may attend the principal changes, and (4) certain exceptional modifications of the phases themselves or their intervening stages. Finally, he points out (5) the directions in which we must look for a choice among what seem the only possible hypotheses capable of explaining the still wholly obscure conditions whereby rejuvenescence of the nucleus is determined. The two extremes (the starting-point and the goal) in the course of a complete division are the resting phases of (*a*) the parent nucleus and of (*b*) the two daughter-nuclei eventually produced therefrom. Half-way between these extremes lies the equatorial plate, that phase which comes just before the very act of division, and to which all the other phases are preparatory or consequent. Strasburger's "nuclear plate" not only designates this phase, but also that which follows; he further employs in the same sense the words "nuclear barrel," or "nuclear spindle," which Flemming would apply more definitely only to nuclei already advanced in division. From the equatorial plate we pass on to the *stellate figures*, for which are used Fol's terms *monaster* (parent phase) and *diaster* (daughter phase), extended by Klein from the nuclei of eggs to those of cells in general. Between the stellate and resting phases come the coiled figures. Thus every cycle involves two series of changes—the first *progressive*, from the parent resting phase to the equatorial plate, the second *regressive*, from the equatorial plate to the final assumption of the resting phase by each of the two daughter-nuclei. The two series have like phases, but in reversed sequence. When the parent nuclear plexus begins to change, it gradually takes up the whole of the chromatin, while its filaments, growing thicker, become disposed at nearly equal distances, and at length the coiled figure results. Segmentation of the coil introduces the figure of the monaster; but the coil may assume the transitional form of a *chaplet* (*Kranzform*), with little or no discontinuity. Every segment is a *loop* (*Schleife*) shaped somewhat like the letter V, with a more or less open, usually rounded, corner, and equal, or nearly equal, straight or twisted legs. [By a curious coincidence, Flemming's own diagram exhibiting the double series of nuclear phases has the same general loop-like figure as each one of the visible elements of which the dividing nucleus is itself composed.] In the constitution of the stellate figures, and their passage to and from the phase of the equatorial plate, the loops undergo very noteworthy alternate changes of orientation. By these *diastoles* and *systoles* each loop is displaced and finally redisposed according to its original bearings, as if guided by an unseen magnet; most of the loops, subject to slight irregularities, being turned round in the same general direction. The free ends of the legs of the loops at first point peripherally; as the monaster changes into the equatorial plate, this position is reversed. But again, in the daughter-nuclei, the loops have their corners directed towards the centres of the nascent cells. The regressive stellate figures lead to the formation of coils by coalescence of the ends of the segments; the coil becomes denser; the chromatin and achromatin are reblended, and the resting phase of the completed daughter-nucleus results.

The most striking attendant (if it be not an essential) phenomenon of division is the longitudinal splitting of the nuclear filaments. This splitting may occur both previous to and during the phase of the progressive stellate figure; in the corresponding regressive phase the filaments are reduced in number, as if longitudinal coalescence of the split fragments of the nuclei had taken place. A few daughter-cells, with two stars, offered apparent exceptions to this law. How to distinguish between the more essential and less general phenomena of nuclear change, is a question which extended researches are required to answer. Some equatorial plates, previous to the diaster-phase, exhibit union of the loops, then arranged in two apposed groups. Flemming regards such union as secondary. The continuity, believed to be general and primitive, noticed by some observers in the filaments of nuclear spindles, hence originally so termed, obtains only as to the pale achromatic threads (Strasburger's "cell-threads," a phrase which Flemming would retain). Of these *achromatic figures*, because of optical difficulties, very little is known. It so happens that they are exceptionally conspicuous in certain vegetable cells, copiously and carefully studied by Strasburger, and in the ova of various animals, subjects of the earlier investigations of Bütschli, Fol, and Hertwig. On these researches were based views of the constitution of dividing nuclei, which have since received notable modifications, both from their authors and others. If, with Flemming (and Klein), we deny that coloured nuclear filaments ever arise from the growth of granules, we may also conclude that the chromatic elements always lie outside, and nowise in the course of, the achromatic threads. The two series of figures, chromatic and achromatic, are quite distinct. Their varying proportions in each nucleus may be one of the most important sources of difference between different cells. The achromatic figure is no less significant than the chromatic. Its filaments are doubtless connected with other pale threads, traversing the extra-nuclear protoplasm. That forces, seated in the achromatic component of the nucleus, are the real initiators and directors of division, Flemming regards as more likely to be true than any other hypothesis we can formulate. The function of the nucleoli has in this respect been greatly mistaken. Better methods may show that they are not even morphological constituents, but mere thickenings or deposits (*Ablagerungen = sequestrata*, or things put aside). Flemming's bold conjecture, that the most obvious phenomena of division, which he himself so carefully discriminates, have in all probability the least significance, has the merit of promoting further inquiry. Equally poetic and scientific is his conception, that the wonderfully striking series of shiftings and transformations, displayed as in a panorama by the coloured filaments, may be ascribed to the influence of pale, almost invisible structures, whose presence, like that of presiding demons, is made known by their works.

The third Section is occupied by the more special topic of spermatogenesis in *Salamandra.* He corroborates v. la Valette's account of the production of spermatocytes from multinuclear spermatocysts, and adds descriptive details as to the indirect division of the nucleus. The head of the spermatozoon lies at first within the nuclear membrane; it is not formed from the whole nucleus, but from the chromatin only. Flemming is not certain as to the mode of development of the middle segment.

In his remarks on technical methods, Flemming cautions us against some sources of disappointment and error, especially as touching the misuse of chromic and picric acids. He recommends slow and careful staining with hæmatoxylin, whenever the finest results are needed. He chiefly employs such preparations, made in great number; in a few cases he has worked with living structures.

Flemming continues to cite the principal contemporary writers on cell-division, and gives a further list of others, both old and new, whom he refers to in his Section on the development of spermatozoa. He selects for more detailed comment those memoirs of Klein, Peremeschko, Schleicher, and Strasburger, which he has seen subsequent to the printing of his first Part. Klein's independent researches very powerfully support most of Flemming's conclusions. Notably is this the case as to the determination of the phases which constitute the regressive series. These have been overlooked, if not as merely existent, in regard to their true connection and derivation, by all other observers, including the acute and painstaking Strasburger. On but one important physiological point do Klein and Flemming differ. Klein believes in the occasional occurrence of direct division among fixed cells. Flemming, otherwise interpreting what Klein has seen (pp. 159–162), considers that such direct division has in no case been hitherto demonstrated, though its possible display by amœboid cells cannot yet be categorically denied. Flemming (p. 169) lays more stress than Klein on the equatorial plate as constituting a definite phase. This phase Klein is inclined to ignore, jumping rather too suddenly from the parent monaster to the regressive stellate figure [but why should not precocious development, i. e. abbreviation, here take place in some instances?]. In describing the monaster of *Triton*, Klein makes no mention of longitudinal splitting. Peremeschko, however, has seen the cleft filaments, without recognizing their full significance. Peremeschko, like Schleicher and Strasburger, errs in deriving some or all of the nuclear filaments from grown granules. He makes other mistakes (pp. 164–9), both of omission and commission, not rightly understanding certain questions at issue between himself and Flemming. More recently, as Flemming shows, Peremeschko appears to have made two very interesting discoveries. He has seen the division of nerve-nuclei, and has also observed the indirect division of white blood-corpuscles. It would now seem that Schleicher (p. 175) has abandoned the points of difference (here concisely summed up by Flemming) between these two investigators. Flemming dwells at much length (pp. 176–184) on the many details, trifling as well as important, wherein he and Strasburger differ. These we cannot now notice. Strasburger and Flemming, nevertheless, essentially agree touching the probability of one general law of cell-development for all animal and vegetable structures.

A third Part is promised in continuation of the present, with an account of the development of the ovarian egg, and references to a valuable paper by Arnold on the cells of tumours.* Already (p. 245) the author compares cell-division to a process of asexual propagation, and uses the researches of Mayzel and Eberth on cell-development in pathological subjects (chiefly the inflamed cornea of the rabbit).

It is scarcely possible to epitomize this long paper, which is at once critical and original, descriptive and speculative, which comes in the middle of a series of current investigations, contains a revision and extension of previous researches, and abounds in necessary repetitions and digressions. Flemming's merits are manifest, both as a critic and independent investigator. On so far-reaching a topic, affecting almost every department of living nature, his work well deserves to be studied *in extenso* with the same carefulness which has guided its preparation.

Formation of Epithelial Cells and Nuclei.†—Flemming criticizes an essay by Dr. Otto Drasch,‡ on the physiological regeneration of the ciliate epithelium of the trachea, and takes this opportunity of showing how so intelligent and praiseworthy an observer has been led astray in his efforts to re-establish erroneous opinions touching the free-formation of nuclei. Flemming further points out how effects due to reagents had in like manner previously deceived both Lott and W. Krause. With Klein and Strasburger, he is prepared to maintain the doctrine—*omnis nucleus e nucleo,*—until the contrary has been expressly demonstrated, and lays just stress on Strasburger's brilliant rejection of the occurrence of "free cell-formation" in the embryo-sacs of phænogams, an exposé which tends strongly to support the belief in one general law of division for all nuclei.

Gastric Epithelium.§—Dr. E. N. v. Regéczy gives a woodcut and description of ciliated cells from the frog's stomach, which resemble the characteristic cells of the duodenum.

Cells of Spinal Ganglia.‖—Dr. B. Rawitz recapitulates some of his predecessors' studies of spinal ganglia, and dwells on the danger of

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* Virchow's Archiv, lxxviii.

† Arch. Mikr. Anat., xviii. (1880) pp. 347–364.

‡ Wien. Sitzb., Oct. 1879.

§ Arch. Mikr. Anat., xviii (1880) pp. 408–11 (1 fig.).

‖ Ibid., pp. 283–301 (1 pl.).

concluding from what has been seen in one class of vertebrates as to their structure in another. He figures and re-describes the cells of the spinal ganglia in the torpedo, frog, guinea-pig, and dog; those of the gasserian ganglion in the pike, frog, triton, and dog. Bipolar cells were seen in fishes only, unipolar cells in batrachians and mammals; reptiles and birds were not investigated. Arnold's spiral fibre is an optic phenomenon due to folding of the sheath. There is still no proof that the cells of the same ganglion are in any way mutually connected, Apolar cells are more common than is supposed, occurring less often in old or higher than in young or lower vertebrates; they are never isolated, but each rests in one sheath with a unipolar cell. The "polar nucleus" of Courvoisier belongs not to the proper ganglionic corpuscle, but to the same category as the other (connective-tissue) nuclei of its sheath, whose endothelium Fraentzel * has already described.

Decompound Gastric Glands.†—Leydig has described the peculiar aggregated gastric glands of the beaver and southern manatee. In the latter, especially, they show an exquisite structure, figured by him in his admirable 'Lehrbuch.' These "decompound" glands, so rare among mammals, are known to be very common in birds. They present various degrees of aggregation, and in this respect are most highly modified in the Rheas, as already stated by Professor Owen.

The huge gastric gland of the American *Rhea* is now adequately described and figured by M. E. Remouchamps. He resolves it into primary, secondary, and tertiary utriculi, the arrangement of which varies in different parts of the gland, and recalls the structure of diverse glandular types among other vertebrates. The secondary utriculi are further distinguished according to the presence, absence, or incomplete development of a canal. The naked epithelial cells of the primary (or ultimate) utriculi, forming a single layer, are all of the same structure. Towards the proximal ends of these utricles, the accumulation of their secretion, including debris of the cells, gives rise to appearances the nature of which M. Remouchamps discusses. Finally, with the aid of diagrams, he explains and extends the classification of the gastric glands of birds proposed by Bergmann in 1862 ('Reichert und Du-Bois-Reymond's Archiv').

Regeneration of Spinal Cord.‡—Prof. M. Masius replies to various criticisms of his previous researches, in conjunction with Vanlair, on repair of the mutilated spinal cord in the frog. He has since extended these investigations to dogs, and compares his results with those of other workers, more particularly Eichhorst and Naunyn.

Puppies between three and four months old had a segment of the cord about four millimetres long completely removed in the region of the fifth lumbar vertebra. In dogs thus treated the hinder limbs are useful as before, but the sphincters lose their power, so that the urine and fæces cannot be retained, and the tail also is quite paralyzed. Amendment of these symptoms began six weeks after the operation.

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* Virchow's Archiv, xxxviii. p. 554.

† Arch. de Biol., i. (1880) pp. 583–94 (1 pl.).

‡ Ibid., pp. 696–717 (1 pl.).

It gradually progressed, and in eight months defecation and micturition were accomplished as in healthy adults. Fourteen months after being injured, these dogs were killed and examined. The several portions of the cord were found united by copious cicatricial connective tissue, within which numerous nervous fibres appeared. No ganglionic corpuscles could be seen.

It is further notable that in such injured dogs, as well as in frogs, the return of motility precedes that of sensibility.

Spinal Root of Optic Nerve.[*]—Dr. J. Stilling recommends his method of teasing asunder nervous strands (*Zerfaserungsmethode*), which comes greatly in aid of transverse sections. By this method he has demonstrated, macroscopically, the presence of a descending optic tract, one of whose bundles he traces back as far as the decussation of the pyramids. Through this path its spinal course must follow.

Thus the views of Goltz, arrived at by way of experiment, are supported. Many details as to the human optic chiasma and its connections are given. The whole will be published elsewhere at greater length.

Retinal Vessels of Fishes.[†]—How are we to explain the contradictory statements about the presence of vessels in the retina of fishes? H. Müller, J. Hyrtl, and Max Schultze denied the existence of such vessels. W. Krause and, more briefly, W. Müller described them in the eel. Most of the other authorities are silent on this subject.

Dr. G. Denissenko now shows how vessels are distributed in the retina of the carp. They occur not only in the innermost layers, but also in the outer granular layer. A figure, from a design by Dr. Heitzman, representing a section through the retina of a young carp, is appended to this paper.

In the adult carp the vessels are insignificant, and might very easily be passed over. In old eels Dr. Denissenko could not see any vessels. He thus corroborates the opinion of W. Krause, that with age these vessels usually disappear, in consequence of the growth of the eye forwards and sidewards, and the simultaneous extension of the optic nerve. In this way the vessels become compressed; their lumen is reduced, and finally obliterated.

True Origin of the Acoustic Nerve.[‡]—Herr C. F. W. Roller describes the course of ascending spinal fibres for the auditory nerve. On the same subject we have also a short notice by R. Wiedersheim.[§] Herr Roller promises further details.

Auditory Ossicles of Mammals.[||]—One of the most pressing questions in comparative craniology is what are the true homologies of the small ear-bones of mammals? Professor W. Salensky, from

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[*] Arch. Mikr. Anat., xviii. (1880) pp. 468–80, figs. 1–4 of a pl.

[†] Ibid., pp. 480–85 (1 fig. of a pl.).

[‡] Ibid., pp. 403–8 (1 pl.).

[§] Zool. Anzeig., iii. (1880) pp. 495–6 (1 fig.).

[||] Morph. Jahrb. (Gegenbaur), vi. (1880) pp. 415–32 (1 pl.).

his studies of young lambs and pigs, more particularly of the former, which yielded a pretty complete series of preparations, comes to the following conclusions. He started from embryos 1·5 cm. long, which as yet showed no traces of cartilage in the visceral arches or about the labyrinth.

A. 1. The proximal segment, at an early period separated from the cartilage of the first visceral arch, becomes the rudimentary *incus* (the second visceral, Reichert's, cartilage here plays no part). 2. The distal moiety of the same cartilage gives rise to Meckel's cartilage (*s. str.*), together with the rudiment of the *malleus*.

B. 1. The *stapes* is formed independently of the other auditory ossicles. 2. It begins as an accumulation of cells around the mandibular artery, acquiring afterwards the form of a trapezoidal plate, which then becomes pentagonal, and finally bell-shaped. 3. From its first appearance the stapes is a perforate and not a solid plate, though wrongly taken for the latter by all embryologists. 4. The course of the mandibulary artery, and the way in which the stapes arises round it, strikingly influences the shape of the stapedial rudiment. The artery conditions the perforation of the stapes, also the annular excavation of the anterior stapedial crus. The *rôle* thus played by the mandibular artery is but provisional. Eventually the artery vanishes, exceptionally persisting in a few vertebrates.

Salensky, accordingly, reverts to the views of Reichert. On these problems the minds of English anatomists have been much exercised by the well-known researches of Professors Huxley and W. K. Parker. Huxley * at first supported Reichert, and subsequently both he and Parker derived the incus from the hyoid cartilage. In certain details, affecting the transformations of this proximal segment of the hyoid among the batrachians (amphibians), Huxley and Parker differ. Gruber's studies of mammals agree in essentials with those of Parker. Kölliker, in the second edition of his 'Entwicklungsgeschichte,' delivered an undecided judgment on this question; he could not, however, confirm the results of Reichert.

New investigations are therefore imperatively demanded to settle data which involve such important issues.

Krukenberg's Studies in Comparative Physiology.—Want of space prevents our doing more than suggest to our readers to study for themselves Dr. C. F. W. Krukenberg's valuable essays on a number of physiological topics, including: the mechanism of the chamæleon's changes of colour,† the respiratory phenomena of various invertebrates,‡ the effects of curaré and strychnine on the lower Medusæ,§ the action of the heart in *Salpa*,‖ the pendulum-like movements of the foot in *Carinaria*,¶ and the relation between the pigment of the liver and the colouring matters of the blood among invertebrate animals (with a plate of absorption-spectra).** There are also two interesting notices on Ctenophora, to which we refer under Cœlenterata, *infra*, pp. 52–55.

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* Croonian Lecture, 1858.

† 'Vergleichend-physiologische Studien,' Part 3 (8vo. Heidelberg, 1880) pp. 23–65.

‡ Ibid., pp. 66–123.

§ Ibid., pp. 124–46.

‖ Ibid., pp. 151–76.

¶ Ibid., pp. 177–80.

** Ibid., pp. 181–91.

Secondary Muscle-wave.*—M. C. Richet describes the phenomena associated with the fact that after each muscular contraction the fibres are in such a condition that they can, without any fresh stimulus, contract a second time. This phenomenon is masked by the fact that, the muscle being then very feeble, slight weights are sufficient to prevent its being apparent.

If we take a very fresh muscle of a crayfish and attach to it a slight weight (say 4 grammes), and stimulate it for one or two seconds by a repetition of strong induction currents, the muscle relaxes as soon as the stimulus ceases; but, a few seconds afterwards, it contracts afresh, and returns more or less to its tetanic condition. This second contraction is effected by successive rhythmical waves, but it is not to be demonstrated if the stimulation is feeble, or if the muscle is weak, or if the weight is too great; in no case was the secondary wave seen when the weight attached was greater than 10 grammes. The author, however, thinks it probable that there is such a wave even in cases where it is impossible to demonstrate it, and he is of opinion that to its existence we owe the remarkable phenomenon of a number of apparently inefficacious stimuli finally making the muscle much more sensitive to such effects.

B. INVERTEBRATA.

Marine Organisms in Captivity.†—Some interesting particulars as to the habits of various marine animals and plants are given by Herr R. Schmidtlein, of the Zoological Station at Naples.

Among animals breeding in the aquarium, none are so easily observed as the larger crustaceans and molluscs, which pair repeatedly and lay great clusters of eggs. Two species of *Maia* (*squinado* and *verrucosa*), pairing from January to July, are good examples of their class. Copulation is most frequent in spring. After many fruitless attempts, the long, awkward legs of each apposed couple duly adjust themselves, and the two animals become firmly interlocked, their sterna being mutually approximated, while the post-abdomen of one is closely pushed against that of the other. The male is underneath; with his huge chelæ he clutches the orbital margins of his consort. The process may last over an hour, and when completed the female resumes her usual position; the male sits upon her, and defends her with his nippers against rival gallants. Zoœæ of these crabs could not, however, be bred, though swarms of Phyllosoma were got from *Palinurus* in the same tank. Lobsters, notwithstanding their salacity, rarely produced eggs in captivity.

Of Mollusca, the best breeders are species of *Loligo*, *Sepia*, *Aplysia*, and *Doris*. *Loligo* lays its eggs, a few days after being captured, on *Posidonia* and rocks. The males of *Sepia*, when sexually most active, display very brilliant colours. *Aplysia* surpasses all other inhabitants of the aquarium in its abundant oviposition; during brief intervals from the work of reproduction, these animals devoured with

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* Comptes Rendus, xci. (1880) pp. 828–9.

† MT. Zool. Stat. Neapel, ii. (1880) pp. 162–75.

astonishing rapidity the *Ulva* around them. Though many nudibranchs lay freely, their eggs never come to maturity.

Not a few of the lower animals and sea-weeds, without any care whatever, thrive and multiply wonderfully. Some succeed but too well, and timely removal is needed to check their excessive encroachment. The physiognomy of the aquarium is indeed notably determined by the rapid growth of (what Humboldt would have called) *social* organisms; within its bounds, as in the "great and wide sea," nature's operations overwhelm those of art. The struggle for life is here instructively displayed under modified circumstances. The actors are the same; the theatre is new.

Compound Tunicata take the lead among these "spontaneous" productions. The graceful Botryllidæ exuberate in both the northern and southern tanks. A transparent species, *Pseudodidemnum crystallinum*, at present predominates above all others. During the previous winter its abundant gelatinous masses stifled numbers of sponges and anthozoans. Of simple ascidians, *Ciona intestinalis* reproduces most copiously; as one generation dies, its place is re-occupied by its successor. Compared with ascidians, Bryozoa are not very generally distributed. *Bugula* is now the commonest, especially in the compartment for eels, where it flourishes along with *Zoanthus* and *Hydractinia.* Mullet and some other fishes, hurtful to various low growths, soon scour the rocks tenanted by ascidians.

In luxuriance of growth the diatoms exceed all other plants. They clothe not only the sides and floors of the tanks, but also their less active inhabitants. Many zoophytes in this way become fatally invested. The larger crustaceans, hypnotized by the unwonted cold of last winter, were often covered with these Algæ. Next in abundance to diatoms come the Oscillariæ.

Few of the higher Algæ thrive in the aquarium. Least delicate seem the firmer species of *Sargassum* and *Cystoseira*, and two species of *Codium* (*bursa* and *elongatum*). Most Florideæ are evanescent in captivity. Dr. Berthold has recently observed fruiting forms of *Chylocladia* and *Callithamnion.*

The tank allotted to Annelids affords a spectacle of great beauty and variety; in short, it is a perfect microcosm. Of its inhabitants, we can only note the young of a species of *Spirorbis*, a well-known commensal of *Palinurus.* This annelid multiplies so fast that much trouble is spent in removing its tubes, shaped like a post-horn, which soon cement themselves with obstinate firmness to the glass windows of the aquarium.

Fishes, if we except Selachians, do not breed well in the aquarium. Otherwise they are flourishing prisoners; the conditions unfavourable to their propagation have not yet been thoroughly ascertained. A work by Costa, published in 1871, records the natural spawning season of numerous fishes in the Gulf of Naples.

Utilizing his own researches and those of others, Herr Schmidtlein has drawn up a serviceable table, with notes on the reproduction and development of several Neapolitan marine animals. The original observer, in every case, is cited.

Pelagic Animals.[*] — R. Schmidtlein gives a tabular list of pelagic animals, with the numbers of each seen near Naples during the twelve months of 1879 respectively. As to time of appearance, the pelagic fauna of Naples includes animals found—

(A.) From October to May. By far the most extensive category. Accordingly, a division of the year into two seasons, term and vacation, seems easy and natural. Here belong most pelagic Mollusca, Ctenophora, and Hydrozoa, excepting the higher Medusæ.

(B.) From June to October. This period is characterized by the predominance of Medusæ Phanerocarpi. Siphonophora and Hydromedusæ are rare. Swarms of *Salpæ* and of *Eucharis*, with other animals belonging to the next category, also appear.

(C.) All the year round.

(D.) After prevailing storms. *Velella* especially may be expected with certainty after severe south-east and south-west gales. *Porpita* is rarer, seldom occurring in fleets. The very much scarcer *Physalia* suddenly became numerous during the spring. With the fleets of *Velella*, such visitors as *Ianthina*, *Lepas fascicularis*, and pelagic cephalopods likewise showed themselves.

(E.) At unforeseen epochs. *Pyrosoma*, rare in 1875 and 1879, was frequent in June 1877. *Pterotrachea*, common during the spring of 1879, scarcely presented itself the following year. *Charybdea*, of which previously but isolated individuals had been seen, became more abundant in November 1879. Next month, for the first time, swarmed *Oceania pileata*. A beautiful *Æquorea* likewise abounded in July and August of the same year.

Mollusca.

Mutual Affinities of the Cuttle-fishes.[†] — The most useful summary of our knowledge of the Cephalopoda, with due reference both to systematic and zootomical details, is still that of Keferstein in Bronn's 'Thier-reich,' 1865. A modification of Keferstein's arrangement has lately been proposed by Dr. Brock.[‡] The same observer identified with Troschel's *Thysanoteuthis rhombus* a female cuttle-fish caught in the Gulf of Naples during the winter of 1879–80. This specimen, nearly half a metre in length, has been dissected by Dr. W. J. Vigelius, whose views as to its affinities agree in the main with those of Keferstein.

Thysanoteuthis is plainly an annectant form, related both to Oigopsidæ and Myopsidæ. It is most like *Ommastrephes* in the former group. But it resembles the Myopsidæ, and particularly *Loligo*, in such characters as the shape and structure of the arterial heart, the habitus and mode of branching of the abdominal aorta, and the formation of the ovarium. Its ganglia stellata have no transverse commissure. Moreover, the conspicuously developed papillæ of its urinary sac are without known representatives in the other Oigopsidæ.

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[*] See reference under "Marine Organisms in Captivity."

[†] MT. Zool. Stat. Neapel, ii. (1880) pp. 150-61 (3 figs.).

[‡] See this Journal, iii. (1880) p. 601.

Yet we must not rashly conclude that the two principal groups of decapod dibranchiate cephalopods have diverged from *Thysanoteuthis*. The structure of the recent Oigopsidæ is too imperfectly known to justify so easy a resolution of their phylogeny.

Affinities of the Cephalopoda.*—Dr. H. von Ihering, after a review of the opinions held by his predecessors, points out that hitherto the questions of their organization have been settled chiefly, if not altogether, by a reference to the Pteropoda; he now expresses his belief that the Lamellibranchs, *Dentalium* and the lowest Arthrocochlides, stand nearer to the Cephalopoda than do the forms just before mentioned. It is scarcely possible to compare the renal or generative organs of the Pteropoda with those of the Cephalopoda. This point is discussed and illustrated in considerable detail; and, after it, the question of the relation of the Dibranchiate to the Tetrabranchiate Cephalopoda.

Here the author advances a proposition which is altogether in opposition to the current views on the subject. This is that we must regard the Tetrabranchiata as being derived from the Dibranchiata, and not the latter from the former. He is of opinion that there is no indication at all of the presence in the Dibranchiate forms of any rudiment of a second pair of gills; so, again, the arms of the *Nautilus* are, as is well known, formed on altogether a different arrangement to those of the Dibranchiata; they would, indeed, seem to have no direct relation to one another. The unpaired oviduct of the *Nautilus* affords support to the proposition; and the fact that in some points *Nautilus* exhibits characters of a less high degree of differentiation must not be taken as the sole criterion of the genetic affinities of the two groups under discussion. Dr. Ihering regards the Octopoda as presenting us with the best idea of the characters of the organization of the most ancient Cephalopoda; lowly points are especially exhibited in the arrangement of their nervous system, where the suprapharyngeal ganglion is still united with the cerebral, and not widely separated from it, as it is in the Decapoda. The author's views are here supported by the embryological investigations of Dobretzky, who has observed that in *Loligo* the ganglia only become separated in the course of development. So, again, Brock's observations on the generative organs show that the Octopoda, as compared with the Decapoda, still show the least modification; their oviducts, for example, being constantly double. The same remark will apply to Vigelius's account of the renal system of these two groups.

Turning to the other line of argument—the palæontological—the author submits that the *Ammonites*, and their predecessors, the *Goniatites*, were dibranchiate forms; the results which have led him to this view have been elsewhere discussed by the author. Here he brings into prominence the fact that microscopical investigation shows that, in structure, that curious organ of the *Ammonites*, the aptychus, is a partially calcified cartilage, which would correspond to the neck-cartilage of the living Decapoda. This point is entered into very

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* Zeitschr. wiss. Zool., xxxv. (1880) pp. 1–22 (1 fig.).

fully, and he concludes by pointing out that two tissues, one fibrous and one hyaline cartilage, are to be made out in the neck-cartilage; the former gives rise to an internal meshwork, such as is again to be detected in the aptychus. A supporting mass of calcified tissue contains a hard body which has taken the place of the macerated hyaline cartilage, comparable to that found by Hasse in the fossil vertebræ of *Squatina*, where calcified layers of cartilage alternate with the hyaline form.

Olfactory Organ of Terrestrial Pulmonate Gastropoda.*—The first object of Dr. D. Sochaczewer seems to be to decide between the claims of the tentacles, the organ of Semper, and the pedal gland, to be regarded as the olfactory organ of these Gastropods. The first of these parts contains a large ganglion each, whence five fibres radiate into the investing epithelium and give rise to terminal knobs, endowed, apparently, with a sensory function. It is not, however, the opinion of all naturalists that these nervous parts are olfactory organs, for some, like Linnæus, have regarded them as having a tactile function; and this view would appear to be supported by the rapidity with which these processes contract when they come in contact with any foreign body.

The original experiments performed by the author in order to arrive at a determination of the question were of the following character:—An example of *Helix pomatia* had its tentacles cut off, and, after the healing process was completed, the snail was placed in the centre of a flat plate, the edge of which was smeared with oil of turpentine. The movements of the snail were very slow and uncertain. When it approached the edge of the plate it behaved itself exactly as did a snail in which the tentacles were completely uninjured, returning at last to the middle of the plate and withdrawing itself into its shell. This and similar experiments seem to show that the tentacles are not the seat of the olfactory sense.

The second organ—the organ of Semper—is next considered. This structure has received its name from the fact that it was discovered by Professor Semper (1856). Small in *Helix*, *Arion*, and *Lymnæus*, it is especially well developed in *Limax*. Here it has the form of four or five glandular lobate processes, which are set at the sides of the mouth. Each lobe is notched on its margin, and from this notch there sometimes extends a shallow groove over the whole of the lobe. The lobe itself has, owing to the presence of a number of slits, the appearance of a three or four-toothed comb, connected together by the complete marginal portion. Semper reported that this organ was very richly supplied with nerves, and, consequently, regarded it as a sensory organ. Dr. Sochaczewer found four fine fibres, of which the two median were recognized to be muscular in character, while the lateral branches are the proper nervi labiales, which only give off on either side a fine nerve-branch to the glandular masses of Semper's organ. The cells of the constituent lobes resemble, as Semper himself pointed out, the glandular cells of the salivary organs, and still

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* Zeitschr. wiss. Zool., xxxv. (1880) pp. 30-46 (1 pl.).

more the secreting cells of the foot-gland. The constituent cells are surrounded by membrane, and lie in a network of connective tissue. It would seem probable that the investing membrane is continuous with the walls of an efferent duct. Histological investigation does not, therefore, speak in favour of this organ having a sensory function, and it does point very distinctly to its glandular nature.

The third organ in dispute—the foot-gland—is looked upon by the author as being the olfactory organ. It is well supplied with nerves, and is of some size. It consists of oval cells, set in the spaces formed by the crossings of muscular fibres, and is placed in the middle line of the foot. The gland is surrounded by two or three circular vessels. The cells are arranged in groups and imbedded in a network of connective tissue fibres. They vary in form, have granular contents, and the nucleus has an eccentric nucleolus. There is an efferent duct for the gland, and the intermediate duct has its walls formed by epithelial cells of two kinds. Most are flattened and cylindrical, and when placed near the cleft in the gland are provided with cilia. The deeper layers contain oval cells, which give off near their surface a delicate rod, which enlarges at its free end into a short ciliated knob, so that they have a close resemblance to the neural cells detected by Flemming in his investigations into the sensory organs of the Mollusca. It results from this that we find in the interior of the body a glandular body communicating with the exterior, in which there are to be detected cells which resemble the sensory cells found in the integument of the Mollusca, and to which, therefore, we should ascribe a sensory function. To determine the function of an organ thus situated would be a matter, perhaps, impossible, and certainly of very great difficulty. That that function is sensory is spoken to by the following considerations:—The three necessary factors of an olfactory organ—the presence of a layer of sensory cells, the entrance of air, and the addition of a secretion from a glandular organ—are here all present; the orifice at the anterior margin allows the air to enter; the olfactive matters contained in it are mixed with the secretion, and so come into contact with the peripheral nerve-cells. The author concludes by pointing out that the sensory arrangements which obtain in the Invertebrata are not to be compared too critically or hastily with those which are seen in the Vertebrata.

Embryo of Planorbis.*—The publication of Fol's researches † induced Herr C. Rabl to repeat his former observations on the embryogeny of *Planorbis*.‡ As touching all points mooted between himself and Fol, Rabl would maintain his previous statements in their entirety. He desires, however, to extend and correct his earlier results on two matters of detail, not in dispute between himself and the Genevese observer.

1. The first of these concerns Lankester's assertion that the orifice of invagination "closes up, and the pedicle so formed becomes the rectum." This had already been disputed by Rabl, who now

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* Morph. Jahrb. (Gegenbaur), vi. (1880) pp. 571–80 (1 pl.).

† See this Journal, iii. (1880) p. 605. ‡ Ibid., p. 235.

further criticizes Lankester's descriptions and figures, and describes what may be seen in preparations specially made to solve this problem. He appends copies from nature of four selected transverse sections, with a schematic figure combining in longitudinal section the views thus obtained. We cite his own concluding summary:—

"In the stage preceding invagination the entoderm consists of ten cells, four small and six large. All these cells divide, and the entoderm invaginates in a sagittal direction. The derivatives of the six large cells, and perhaps also of some of the four small, incept albumen and become albumen-cells. A number of the derivatives of the small cells do not, however, undergo this metamorphosis, but retain their abundant granules. Since, now, the entodermal tract is not limited posteriorly by elements which have become albumen-cells, the small richly granular cells must form after complete invagination a plate or string, not only bounding the cavity of the gut behind but also reaching as far as the skin [ectoderm]. That the string in question is on either side bounded by albumen-cells and at first possesses no lumen—further supports this interpretation.

I am still, therefore, of my former opinion that one ought not to speak of a 'pedicle of invagination.' Yet a string or plate exists, which gives rise not only to the wall of the rectum, but also to the cylinder-cells of the middle-gut."

2. The precise mode in which the middle layer makes its appearance is the subject of the second topic discussed in Rabl's short but important paper. As soon as the stage of twenty-four cells is reached, one of the four large vegetative cells, behind the transverse furrow now becoming shorter, gives rise to a small daughter-cell which comes to lie in or upon the furrow, and is with difficulty visible. There are now, therefore, twenty-five cells, and the large residual vegetative-cell just mentioned is the first cell of the mesoderm.

Between this cell and the two contiguous endodermal cells a pair of small cells (one on each side) appears. These are formed by the intrusive elongation and fission of two cells from the adjacent ectoderm.

Each of the three large endodermal cells, companion-cells of the mother-cell of the mesoderm, now becomes pear-shaped. The narrower end, pushed towards the vegetal pole, is segmented off like a bud. At the animal pole, likewise, further segmentation sets in, inaugurated by the division of the four ectodermic cells, which are richer in granules than their fellows. But at this stage the vegetal pole is the seat of more significant changes.

The entire number of vegetal cells has, therefore, increased to eight, or seven endodermal and one mesodermal. Next, the latter divides into a pair of cells. Division of the three larger endodermal cells follows. Then the two mesodermal cells are thrust back into the cleavage cavity.

Finally, Rabl compares this young of *Planorbis* having twelve vegetal cells (ten endodermal and two mesodermal) with the embryo of the rabbit, as represented by E. van Beneden. Multiply by eight the cells of the former; it would then have ninety-six vegetal cells, no longer disposed in one but in two or three layers, just as in the rabbit. In both, the endodermal cells change their character sooner than the mesodermal. The latter (according to hypothesis, sixteen instead of two) scarcely yet show a bilaterally symmetrical arrangement. Such an arrangement would first become manifest when each moiety of eight cells further proliferated, and the whole mesoderm assumed the shape of a horseshoe or crescent with its concavity directed forwards. This stage corresponds to E. van Beneden's ninth, or to *Planorbis* in Fig. 19 of Rabl's former paper. We thus trace the initial resemblances among developing bilateral animals, vertebrate or invertebrate.

Five stages of the egg during segmentation, as seen from the vegetal pole, are figured. All the figures are taken from *P. marginatus*, which, like *P. carinatus*, would seem to have smaller endodermal cells (less crowded with yolk-granules) than *P. corneus.*

Development of Paludinidæ.—In a note to his previous paper, Herr Rabl adverts briefly to the development of *Bithynia*, the study of which he began during the spring of 1880. In both genera the primitive renal organs arise in the same way, each being produced by the excavation of a large specialized mesodermal cell. Bobretzky has mistaken for primitive kidneys parts of young prosobranchs which are homologous with the lateral vacuolated regions of the velum of *Planorbis.*

The supra-œsophageal ganglion of *Bithynia* also originates just as in *Planorbis.*

The cells of the entoderm divide into cylinder-cells, albumen-cells, and yolk-cells.

Pedal Nervous System of Paludina vivipara.*—Dr. H. Simroth, already known by his interesting researches into the mode of locomotion of the Mollusca, here deals with an important factor of the phenomena he has already described. The massive retractor pedis of the mollusc in question can be easily divided into two lateral halves. The removal of these retractors can be effected without any removal of the nerves—a certain proof that the nerves in question expressly supply the foot itself. This foot is also rich in blood-lacunæ. Between the median one and the lateral there is a thick branch of the pedal nerve, which diminishes in size as it passes backwards. Four commissures connect together the trunks which are given off from the pedal ganglion, and of these the second is the widest; and it also is seen under the Microscope to give off nerve-branches. The branches given off from the pedal nerves follow one another with great regularity, and they can be separated into an internal and an external series. The first of the inner set has an interesting course. After passing a little backwards and downwards, it turns round and goes forward to supply one-half of the anterior edge of the foot. It early divides into two branches, one of which has a lateral course and is stronger than the median one, which runs almost directly forwards; these two branches are connected by anastomosing ramules.

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* Zeitschr. wiss. Zool., xxxv. (1880) pp. 141–50 (1 fig.).

The morphological interest of these and other observations of Dr. Simroth's lies in the fact that von Ihering has divided the class of Gastropoda into two phyla. One, that of the Arthrocochlides, he derives from the Gephyrean-like forms (*Amphineura*) *Chætoderma* and *Neomenia;* the other he calls the Platycochlides, and for these he finds ancestors in the Dendrocœlous Turbellaria. The central ganglion of the first order (Protocochlides) of the Platycochlides is by that author regarded as consisting of a single dorsal mass, from which arise two pedal nerves, not connected one with the other. On the other hand, the Placophora or Chitons, which are regarded as being intermediate between the Amphineura and the Arthrocochlides, have the brain consisting of an obscurely differentiated œsophageal ring. To this ring there are attached, among others, two well-developed pedal nerve-trunks, which are connected with one another by numerous transverse commissures. This step-ladder system is obviously enough to be recognized, as Simroth shows, in the Paludina, and it consequently follows that this creature is one of the Arthrocochlides, were it not possible that it had been obtained independently, and in consequence of an adaptation. This latter view is supported by the comparatively small number of commissures which are found in this Pulmonate; but to this it may be answered that there has been a fusion of the commissures. Difficulties such as these are insisted on by the author, who comes to the conclusion that questions, but no answers, are suggested by the study of the nervous system of this animal. Some answers must, however, be found, and it is possible that great assistance may be gained by an investigation of the anatomy of *Neritina* and *Valvata*, for specimens of which the author makes an appeal.

New Nudibranch.*—Dr. R. Bergh, our great authority on this group, describes a beautiful nudibranch from the Mediterranean under the name of *Peltodoris atromaculata* Bgh. *P. crucis* (Oersted), from the Antilles, formerly placed by Bergh in *Discodoris*, is now transferred to the "new" genus. Both species share with diverse *Dorids* and a few other molluscs the curious property of parting with fragments which break away from the margin of the mantle.

Peltodoris Bgh. comes nearest to *Discodoris.* It has similar tentacles and gills, a large prostate, an unarmed penis, and other characters of this genus, from which its smooth lip, destitute of armature, at once distinguishes it. It is also of firmer consistence.

But one specimen was available for dissection. Dr. Bergh figures the entire animal (coloured in profile), its cephalic ganglia, ear-sac with otocones, dental armature, and accessory genital apparatus.

New Archaic Mollusc.†—Dr. A. A. W. Hubrecht describes a new genus, to which he gives the name of *Proneomenia* (*Sluiteri*), and which, he says, closely resembles *Neomenia carinata* in many of its anatomical details. In external form it is cylindrical; the anterior is thicker than the posterior end; the mouth and anus are on the ventral surface, and the latter is continuous with the delicate ventro-median groove. The

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* MT. Zool. Stat. Neapel, ii. (1880) pp. 222-32 (1 pl.).

† Zool. Anzeig., iii. (1880) pp. 589-90.

calcareous spicules of the epidermis are imbedded in a cuticle of great strength, and chitinous in character. The spines are in all cases obtusely acicular. In the ventral wall of the pharynx there is a small slit-shaped orifice, which leads into a short saccule, and in this there is formed a small but very distinct radula. This organ, just as much as the salivary glands, which are found in this new genus, is absent from *Neomenia*.

There are distinct signs of the presence of an organ of Bojanus in the formation, near the anus, of a glandular body, which is traversed by ciliated canals, and is found to contain black concretions. Some of these canals appear to have, in addition, internal orifices. To the right and left of the anus there is yet another glandular organ, which is enclosed in a quantity of muscle. Masses of fine fibres, which appear to be secreted by this double gland, lead to the hypothesis that we have here the representation of the byssus-gland.

Dr. Hubrecht promises further details as to this creature, of which two specimens were dredged by Dr. Sluiter in Barents Sea. They measure respectively 105 and 148 mm.

Molluscoida.

Tunicata of the 'Challenger' Expedition.*—The Tunicata of this expedition have been confided to Dr. Herdmann, whose preliminary report is now issued. He states that the entire collection contains from 150 to 200 species, the majority of which are new to science.

Dealing first with the Ascidiadæ, or simple Ascidians, in which (1) the body is sessile and attached, (2) the branchial aperture eight- and the atrial aperture six-lobed, (3) the test gelatinous or cartilaginous, (4) the branchial sac ordinarily papillated, and (5) with unbranched filiform tentacles. He finds that of the already known genera two (*Rhopalœa* and *Rhodosoma*) are not represented. On the other hand, there is a new genus, *Abyssascidia*, and a new sub-genus (of *Ascidia*), *Pachychlœna*.

Abyssascidia has about twelve lobes to the branchial and eight to the atrial aperture. The branchial sac is not longitudinally plicated; the viscera are on the right side of the branchial sac; the intestine is small, the stomach short and wide. Only one species is as yet known —*A. Wyvillii*—which was taken at a depth of 2600 fathoms in the seas south of Australia. Dr. Herdmann is of opinion that this new form has relations to *Ascidia* and to *Corella*. The sub-genus *Pachychlœna* has a very thick and solid test. The species ranged under it are *P. oblonga*, *P. obesa*, *P. gigantea*. The other new species described in this paper are *Ciona Flemingii*, *Ascidia meridionalis*, *A. vasculosa*, *A. translucida*, *A. tenera*, *A. pyriformis*, *A. falcigera*, and *Corella japonica*. A table indicating the affinities and characters of the known species is given.

In a second communication † Dr. Herdmann describes *Ascidia cylindracea*, *A. despecta*, and *A. placenta* as new species, and then proceeds to an account of the *Clavelinidæ*, which family, like many of the

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* Proc. Roy. Soc. Edin., 1879–80, p. 458.

† Ibid., p. 714.

older naturalists, he places under the *Ascidiæ simplices.* He discusses their proper systematic position, and, as against those who would look on them as being intermediate between the simple and the compound Ascidians, he points out that the power of reproducing by gemmation has a more apparent than real importance. "The buds on the stolons of the *Clavelinidæ* are developed from the ends of the blood-vessels, and are at first merely slight enlargements similar to and comparable with the knobs on the end-twigs of the vessels in the test of an *Ascidia*, these last vessels being comparable with those in the stolons of the *Clavelina.*" In fact, the simple Ascidians have been observed to form stolons, though gemmation is not known to occur. In fine, the author forms a family—the Clavelinidæ—to contain those simple Ascidians which reproduce by gemmation and form colonies. In addition to *Clavelina*, *Perophora*, and, possibly, *Rhopalæa*, this family contains a new genus, *Ecteinascidia.* Like *Ciona* and *Rhopalæa*, it has well-marked internal longitudinal bars, but, unlike them, it has no papillæ to its branchial sac. Three species are placed in this genus, all of which are new—*E. crassa*, *E. fusca*, and *E. turbinata.* *Clavelina oblonga* is a new species, as is also *C. enormis.* Of the latter the author notes a specimen which is evidently "pathological"—two individuals being in adhesion, and having an irregular stem-like base, which seems to owe its development to the irregular surface to which the colony was attached.

North Polar Polyzoa.*—The number of species of Polyzoa brought home from the North Polar Expedition is not large, as the present list only consists of fifteen species, of which Mr. G. Busk considers three new; the remainder are all known, and mostly common in the Northern Seas.

The new species are named *Flustra serrulata, Eschara perpusilla, Farella* sp.

Metamorphosis of the Bryozoa.†—M. J. Barrois gives a detailed account of the different stages of the development of the Escharine group of the Bryozoa, in which he is enabled to connect them better than was done in his own well-known previous memoir and those of other investigators.

Stage 1. *Blastula.*—Consists of eight rows of five cells each, running parallel to the long axis of the ovum, to the poles of which the two lateral rows alone extend, and round which they form a ciliated zone. Stage 2. *Gastrula.*—Formed by the invagination of four large cells on the oral surface. The aboral series of cells become transversely segmented; those of the ciliated zone longitudinally so; the median cells of the aboral face elongate, producing a cross. Stage 3. *Rounded Embryo.*—Has the same general shape, viz. rounded oblong, with the long axis at right-angles to the invagination-orifice, as in the last stage. The four invaginated cells form eight or nine cells by segmentation; of these, a central raised mass, in which the individual cells are difficult to distinguish, becomes free from the

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* Journ. Linn. Soc. (Zool.), xv. p. 231 (1 pl.).

† Ann. Sci. Nat. (Zool.), ix. (1880) Article No. 7, 67 pp. (4 pls.)

rest and from the walls of the cavity, forming the *endoderm;* the remainder form two lateral masses adhering to the outer wall (*ectoderm*), constituting the *mesoderm*, with somewhat the characters of a "germinal streak." The endoderm and mesoderm re-unite to act as a nutritive vitellus. Stage 4. *Cylindrical Embryo.*—The cells of the *zone* increase greatly in height, and form most of the sides of the embryo, which is now almost globular. A cap consisting of radiating cells, is formed from the ectoderm beneath the epidermis at the aboral pole. At the posterior side of the oral extremity an invagination is formed, and forces its way into the interior, becoming a very large organ, the *sac* (*stomach* of the author's former memoir); in front a rounded organ of doubtful origin appears, at first unattached; this is the "*glandular organ.*" Stage 5. *Oblique Embryo.*—The form is elongated from the oral to the aboral end; by the superior growth of the posterior cells of the ciliated zone, as compared with the front ones, the hind face becomes much longer than the front face; the latter is, therefore, thrown to the side, and the shape of the embryo becomes oblique and asymmetrical. The *sac*, now very large, still opens at the oral pole, while the *glandular organ* faces towards the oblique part of the hinder pole, and henceforth forms a part of the ciliated zone. At the aboral pole a lateral invagination (formerly termed the *rudiment of the sucker*) forms the pallial cavity, and extends as far as the ciliated zone. The front part of the central region of the oral face consists of large flat cells, the peripheral portion of small cylindrical cells; the space between is pushed inwards, to form the ciliated aperture; a group of cells which radiate from its anterior part carries the plumule. The glandular organ unites with those cells and with the ciliated aperture to form the *pyriform organ.* From the lower part of the ciliated aperture two small lobes become marked off. The vitelline mass now becomes degenerated into a number of globules scattered in the general cavity.

Metamorphosis:—Stage 1. *Half-open Larva.*—The sac is evaginated through the orifice by which it was invaginated, and forms a quadrangular base for the fixation of the embryo. The peripheral part of the oral face is forced into the interior below the ciliated zone, which closes over it all, with the exception of the two small lobes. The ciliated zone also covers the whole aboral aspect, which now consists of long cells and spreads out and becomes thin in proportion as the pallial cavity increases in size.

Stage 2. *Umbrella-shaped Larva.*—The zone, fixed at the central part of the oral face, is turned back, thus causing the disappearance of the pallial cavity; and the surface of the aboral face grows outwards, and extends an umbrella-like sheet of substance over the inverted zone; this curves over towards the base and then comes into contact with the quadrangular plate of fixation, and forms the interior wall of a cap whose exterior is formed by the aboral suspension. The central part of the oral face becomes a short connecting tube.

Stage 3. *Lozenge-shaped Larva.*—It is the *sac* which gives the embryo this shape when seen from the aboral end, owing to two lateral folds which project from it. A slight posterior indentation marks the anterior end of the future cell, which thus faces in an opposite direction to that in which the embryo faces.

Stage 4. *Rounded Pentagon.*—The two angular folds become narrow and turn towards the top. The aboral face becomes united by its edge with the quadrangular base; its lower edge becomes severed from the rest, and remains attached to the base, forming the skin or wall which constitutes the future cell. The rest of the plate still remains in contact with the ciliated zone, and forms a broad ring, occupying, with the intestine, all the interior of the embryo. A thickening appears internally, corresponding in position to the cap on the outside, and forms the *internal epithelial layer.* The two small lobes which originated from the ciliated aperture unite with the pyriform organ, forming a thickening which is the origin of the *external muscular layer* of the polype.

Stage 5. *Rectangular Oval.*—Besides changing its shape, the embryo has the cap and the internal epithelial rudiment pushed into the interior; the internal ring formed by the ciliated zone, &c., degenerates, commencing with its internal part; the pyriform organ also degenerates. The external part of the internal ring assumes a horseshoe shape, and its protoplasm becomes granular. This, with the epithelial and muscular rudiments, which come into contact by growth, constitute the whole internal organization.

Stage 6. *Square Embryo.*—The cells of the skin become distinct, and secrete a cuticular envelope. The anterior part becomes divided into two lobes by the union with the invagination-opening of the indentation which forms the cell.

Stage 7. *Polypide with Primitive Peduncle.*—The muscular has entirely enveloped the epithelial rudiment. The polype-rudiment extends from the orifice of invagination to the base of the horseshoe. The horseshoe is entirely composed of globules. The primitive cell-cavity begins to disappear, and that end of the body in which it lies becomes rounded.

Stage 8. *Stage of complete Degeneration.*—The polype-rudiment loses its connection with the horseshoe, and contracts into a round mass suspended from the body-wall; the invagination orifice closes. The globules composing the horseshoe become scattered. The distinction between the orifice and lower surfaces of the cell becomes more marked.

Summing up the main deductions from these facts, the author considers that Grant's theory of retrograde development, as applied to this case, must be abandoned. The development of the body and its organs is uninterrupted from the egg to the adult, but its regularity is disturbed by the loss of organs which occur in the larva, but are not preserved in the adult.

In its main features the development is *meroblastic*, although the earliest period presents in the Escharines a truly holoblastic condition. The intestine, as a coherent organ, is entirely wanting in the embryos of *Ectoprocta*, by which point, as well as by the possession of a mantle, they differ from the *Entoprocta.* A true mantle is represented by the membrane which lines the pallial cavity and, therefore, exists in *Chilostomata* as well as in *Cyclostomata;* in the *Lophopoda*, the vestibule and the annular fold which forms it represent the pallial chamber and the mantle respectively. The most striking feature of the development is the fixation of the embryo by the oral end. With this is connected the inversion of the mantle towards the point of fixation, the inverse of what takes place in the Brachiopoda.

The fate of the chief parts of the larva is as follows:—The aboral face forms the wall of the cell, or a considerable part of it, and also, by invagination, the epithelial layer of the polypide. The ciliated zone entirely disappears. Much of the oral face disappears, but forms part of the wall of the cell, together with the rudiment of the internal muscular layer.

Arthropoda.

α. Insecta.

Olfactory Organs of Insects.*—The chief results of G. Hauser's histological investigations into the structure of these organs may be thus summed up:—

In all Orthoptera, Pseudoneuroptera, Diptera, and Hymenoptera, as well as in many Lepidoptera, Neuroptera, and Coleoptera, a strong nerve arising from the cerebral ganglion passes into the antenna; there is a sensory terminal organ, formed by bacillar cells developed from the hypodermis, with which the nerve-fibres are connected. In addition to these parts there are supporting and accessory organs formed by the pits or cones which are filled with fluid, and which are invaginations or processes of the epidermis. If we select the Orthopterous *Calopterus italicus* for a more detailed study, we find that the antennæ are setiform, but rather wider at their middle than at the base; they are made up of twenty-two joints, the surface of which is divided by grooves into a number of small, somewhat elevated areas, rhomboidal in form. On the basal and a few succeeding joints stiff tactile setæ may be detected; on the eighth or ninth we find, in addition to these setæ, rounded, irregularly shaped orifices, covered over by a delicate membrane and surrounded by a chitinous wall; these may be arranged singly, by pairs or in groups, and as many as fifty pits may be found in one joint; within the pits we find serous fluid. The bacillar cell already mentioned is connected with a pretty strong nerve-fibre. Among the Coleoptera we find that *Melolontha vulgaris* (male) has 39,000 of these pits, and the female 35,000; in *Dytiscus marginalis* they are said to be very distinct.

The functions of the organs were investigated by a series of experiments. The antennæ having been extirpated, the insects, which had previously been tested in the presence of such highly odorous bodies as turpentine, carbolic acid, and so on, were again tried, and exhibited no repugnance at all in the presence of these compounds. It was also found that when the antennæ were removed the insects did not rush to food. Observations on the value of the antennæ to the males in seeking out the females were not completely satisfactory.

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* Zeitschr. wiss. Zool., xxxiv. (1880) pp. 367–403 (3 pls.).

The bearings of the characters on the doctrines of natural and sexual selection are discussed in the concluding portions of the paper. It is interesting to note that the Libellulidæ, and especially the larger species, are forms in which the optic organs appear to be remarkably well developed, while their olfactory pits are proportionately small in number as compared with other Orthoptera; so again the plant-eating Hymenoptera require less assistance than the saw-flies, and we find consequently, *Ichneumon* with 5000 pits on each antenna, and *Lyda* with only 600. In the sexual relations we find similar evidence; the nocturnal Lepidoptera have the antennæ so developed as to form a secondary sexual character, and very much the same obtains in those cases in which the females lead a retired life. One example will suffice—the male of the Hymenopterous *Lophyrus* is distinguished from its female by the development of its antennæ, and the female is heavy and inactive.

Structure of the Stigmata of Insects.[*] —Dr. O. Krancher, in a preliminary communication, points out that these organs may be grouped under five types of structure:—

I.—Stigmata without lips.

(*a.*) The simplest stigma is represented by a cleft, which is kept constantly open by a chitinous ring (abdominal stigmata of Diptera, &c.).

(*b.*) The stigma consists of a series of separate stigmata, which are generally surrounded by a common chitinous ring, and which have their tubular processes united into a single trachea (Dipterous larvæ and pupæ).

II.—Stigmata with lips.

(*c.*) The lips are represented by chitinous pads, simple in structure, and not richly provided with hairs.

(*d.*) The lips are turned inwards, and are invested by special hairs, which frequently unite to form a close network.

(*e.*) The round stigma has on one side a median piece projecting towards the centre.

As to the number of the stigmata, great variations obtain, but never more than ten pairs are found; they are most conveniently divided into thoracic and abdominal stigmata. Of the former there are generally two pairs; in the Pulicidæ, however, there are three pairs. The abdominal stigmata are frequently found on the dorsal surface, and they are always set symmetrically. The position of the orifices seems to depend largely on the habits of the insect.

The apparatus for closing the tracheæ consists of three chitinous bars, moved by a special muscle. Like the stigmata, it presents great variations; but this much is certain, that it is wanting in no insect. The author regards this apparatus as being morphologically nothing more than a local thickening of the spiral fibre of the trachea; and this view is supported by what obtains in the simplest cases, where

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[*] Zool. Anzeig., iii. (1880) pp. 584–8.

the trachea is at certain points surrounded by a ring made up of several layers of chitin.

Wings of the Hymenoptera.[*]—Dr. W. Breitenbach points out that in an almost completely developed wing of a pupa of a Hymenopterous insect it is possible to see that it is folded in very various ways; hitherto no connection between these foldings and those of the adult wing have been ever detected. Bearing in mind that the wings are traversed by tracheal branches, which are invested by a thick layer of chitin, and that the whole surface of the wing is covered by small, closely-set hairs, we have further to note that at some points the chitinous layer is almost or altogether completely absent, while the tracheæ are reduced and the hairs sparse. Such points may be united by a line, rendered evident enough by the slight development of the hairs thereon. These peculiarities enable us to distinguish the position of the embryonic folds, which were present along these lines; and the absence of the hairs and the feeble development of the chitin is at once to be ascribed to the mere mechanical fact that along these lines there was not sufficient room for them to be developed.

Development of the Dorsal Vessel of Chironomus.[†] — Herr A. Jaworowsky deals especially with the musculature of this vessel, and believes that he has succeeded in demonstrating that it, and the valves, are derived from a bilateral rudiment, or, in other words, from two distinct rows of cells. His studies on post-embryonal development lead him to the conclusion that there is a muscular cell for every nucleus found in the contractile wall of the dorsal vessel; that each circular muscle consists of two lateral cells, which only partly fuse with one another in the middle line; while the valves themselves are derived from part of the muscle-cells.

These three conclusions are severally supported by the following observations. (1) In a larva of *Chironomus variegatus* one day old, each of the two lateral walls of the dorsal vessel is seen to consist of a series of spindle-shaped elements, with a distinct round nucleus; the contents of the cells are finely granular and but feebly refractive, and it is to this last circumstance that we must ascribe their having been so frequently overlooked; (2) a series of observations demonstrate that the ends of the spindle-shaped cells elongate in the direction of the middle line, part of each becomes connected with that of its fellow, and between the rest of each cell there extends a tendonous band. The physiological independence of the two sides was spoken to by an experiment in which the author found that the final contractions of the cardiac tube took place on one side only, and, during its systole, only the wall of one side was drawn towards the middle line. (3) The nucleus of the muscle-cell, which is visible during the systolic period, becomes obscured at the diastole; at the beginning of the systole the contractile vessel turns toward the dorsal wall, and the consequence of this is that the lateral part of the muscle-cell projects into the lumen of the vessel; so that there is periodically a greater

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[*] Zool. Anzeig., iii. (1880) pp. 522–3.

[†] SB. K. Akad. Wiss. Wien, lxxx. (1880) pp. 238–58 (5 pls.).

development of the valvular arrangements. Where proper valves are developed it is obvious that we have a higher differentiation, inasmuch as there is a wider division of labour.

Paltosoma torrentium, a Fly with Dimorphous Female.*—This species,† already distinguished by its very remarkable larva, has been found by Dr. Fritz Müller to possess two forms of the female, differing so widely in the size of the eyes and in the structure of the mouth-parts and feet as to lead to the inference that they have entirely different habits of life. The case is a different one from that of dimorphous females of Lepidoptera, for here neither female can be said to resemble the male more closely than the other. The imagines have not yet been reared from the pupæ, as the latter die when removed from their native streams, but the fully developed insects have been removed from pupæ which were ready to burst, and the identity in species of the male and the two females has thus been determined.

The *eyes* serve readily to distinguish the three forms: in the male they cover nearly the whole head and meet at its apex, excluding the accessory eyes, which are placed on a special posterior pedicel; in one form of the female they include the whole length of the head, but leave a broad space between them on the vertex; in the other females they are scarcely half so long or broad.

The *mouth-parts* are fully present in the large-eyed female alone; the labrum is pointed, and has the shape of a somewhat broad dagger; its edges are smooth, and look right and left; beneath it lies another style, narrower, toothed at the edges, and traversed by a canal, and representing the poison-organs of the blood-sucking Diptera; to the right and left of this lie the long, narrow, and thin mandibles, armed with teeth on their inner edges. The first pair of maxillæ are weak and bristle-like; the fused second pair acts as a sheath enclosing all the mouth-parts, and has a pair of palp-like organs on its upper side. The essentially blood-sucking characters of these parts are wholly wanting in the other—the small-eyed—female, and in the male. In them the maxillæ are entirely absent, the median style which lies behind the labrum has no teeth, and its canal opens on its upper, not under, surface. The main difference between the male and the small-eyed female is that the apex of the labrum is hirsute in the one, naked in the other.

Differences similar to these which exist between the one female on the one hand, and the male and other female on the other hand, are known to occur between the sexes of those Diptera whose females suck the blood of Mammals, and in several cases the honey-sucking habits of the males have been observed.

The differences between the *feet* in the three forms consist in the slenderness and length of the terminal joint, which has a simple and relatively small ($\frac{4}{11}$ of its length) claw, in the small-eyed female; in the large-eyed female the claw is $\frac{4}{5}$ of the length of the last joint, and beset with hairs; in the male the length of the claw is intermediate

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* 'Kosmos,' vii. (1880) p. 37.

† See this Journal, *ante*, p. 616.

between the lengths of the two others, and its entire lower edge is toothed like a comb.

The reason of the large eyes and grasping feet of the one female appears to lie in the requirements of its search after and firm grasp of its prey, acts which are devoted to sexual purposes in the similarly organized males. The question whether the European species of the genus exhibit a similar dimorphism in the females is an interesting one; in any case, however, their ancestors must have had but one form of mouth. Another instance of difference of alimentation between the male and female is offered by several bees (e. g. species of *Euglossa*, *Melissoda*, *Xylocopa*), the two sexes of which appear to frequent different plants.

Dorsal Blood-vessel of some Ephemerid Larvæ.*—Herr O. Zimmermann directs attention to the special arrangement by means of which the blood from the median dorsal vessel of such a larval form as that of *Cloë diptera* is enabled to pass, not forwards, but backwards into the caudal setæ; the forward movement of the blood in the contractile tube is, as he shows, effected by the presence of a series of valves which prevent the blood from passing backwards; in the terminal segment, however, the valve is turned not forwards but backwards, and so it happens that when the last chamber contracts, the blood has to pass into the caudal appendages. From these caudal vessels the blood passes through an elongate-oval orifice into the cavity which surrounds the vessel, and from this it is slowly driven forwards.

The physiological purpose of this arrangement would appear to be of a respiratory character, an exchange of gases being easily effected through the integument of the setæ. The author also notes the presence of another peculiarity: the development, on the surface of the mesothoracic portion of the vessel, of a stalked vesicle, which is directed backwards and contracts irregularly.

β. Myriapoda.

Essays on Myriapods.—The first part of the new (47th) volume of the 'Archiv für Naturgeschichte' is almost wholly devoted to the Myriapoda. Dr. E. Kolrausch † issues a complete revision of the Scolopendridæ, with two plates. Save where lack of material compels him to accept a few of the groups of others, his 15 genera and 103 species are based on new and careful estimates of the systematic value of external characters. Dr. F. Karsch ‡ analyzes the curious genera *Sphærotherium* and *Sphæropœus*; and in a second paper he describes several unnoticed species of *Polydesmus* and directs particular attention to the male genital appendages. A specimen of *P.* (*Euryurus*) *tænia*, in the Berlin Museum, shows on one side a well-formed organ of copulation, paired with an unmodified limb on the other. Dr. Karsch thinks we may have here an example of a "morpho-hermaphroditic" Myriapod. Each of these two papers has a crowded plate, representing the external genitalia of numerous species. In a third

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* Zeitschr. wiss. Zool., xxxiv. (1880) pp. 404–6 (4 figs.).

† Arch. f. Naturgesch., xlvii. (1880) pp. 50–132 (2 pls.).

‡ Ibid., pp. 19–35 (1 pl.); 36–49 (1 pl.).

essay,[*] Dr. Karsch enumerates the Myriapods (and spiders) obtained during Rohlfs' African expedition.

The first part of a monograph on the Austro-Hungarian Myriapods, by Dr. Latzel, has also appeared,[†] the class being divided into four orders, Chilopoda, Symphyla, Diplopoda, and Malacopoda. The Chilopoda are alone dealt with in this first part, of which 31 genera are recognized (15 European). *Stigmatogaster* (European) and *Notophilides* (American) are nov. gen.

Dr. Latzel says that pinned specimens of Myriapoda are of no use, and that they should be preserved in spirits of wine in well-corked glass tubes.

Professor Tömösváry [‡] gives a revised list of Hungarian species, as supplementary to Latzel's monograph. *Mecistocephalus hungaricus* and *Geophilus paradoxus* are for the first time described, together with two nov. spec. of *Lithobius.*

Eyes of Myriapods.[§]—In his monograph on the visual organ of Arthropods, Prof. H. Grenacher discussed the eyes of Insects, Arachnids and Crustaceans, but not of Myriapods. The fauna of temperate Europe scarcely affords suitable materials for these delicate investigations. Grenacher now describes sections of the eyes of a number of exotic Myriapods. These are figured on two very attractive plates. In the mean time two independent observers, Sograff (author of a Russian memoir on *Lithobius*, published in 1880, at Moscow [‖]), and Graber,[¶] have also studied the same subject. Grenacher adds much to what they have ascertained, and corrects some serious errors into which Graber seems to have fallen.

Comparing the simple eyes of some Arthropods with the typical facetted eyes of Insects and Crustaceans, Grenacher had demonstrated elements common to both, in the well-known retinal cells. These elements Graber would deem multicellular, ascribing to them two to three nuclei. But Grenacher contends that Graber has here made three simultaneous mistakes: he has described the presence of nuclei where no such bodies exist, has mistaken other structures for nuclei, and missed the nuclei themselves. By an unhappy fatality Graber confirms Grenacher in a wrong account of the retina of *Epeira*, not corrected by the latter until after his book was printed. Graber also misinterprets Grenacher's discovery of the peculiar dimorphism of the retinal elements which one and the same Arthropod may display. These, with further particulars as to the eyes of spiders and scorpions, for the sake of comparison with Graber's results, are given by Grenacher, in an introduction to his present memoir.

The eyes of different Myriapods differ greatly, contrary to what has hitherto been supposed. Grenacher distinguishes those of (1) Scolopendridæ, (2) *Lithobius*, (3) *Julus*, (4) *Glomeris*, and (5) *Scutigera*.

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[*] Arch. f. Naturgesch., xlvii. (1880) pp. 1–14 (1 pl.).

[†] Latzel, R., 'Die Myriopoden der Oesterreichisch-ungarischen Monarchie. Erste Hälfte. Die Chilopoden,' 228 pp. (10 pls.). (8vo. Wien, 1880.)

[‡] Zool. Anzeig., iii. (1880) pp. 617–19.

[§] Arch. Mikr. Anat., xviii. (1880) pp. 415–67 (2 pls.).

[‖] See also Zool. Anzeig., ii. (1879) No. 18.

[¶] Arch. Mikr. Anat., xvii. pp. 58–94 (3 pls.). See this Journal, iii. (1880) p. 61.

All except the last are stemmata. *Scutigera* (= *Cermatia*) has compound eyes of a very anomalous type, in no wise resembling that of Insects and Crustaceans. Without copying his figures, we could not usefully abbreviate Grenacher's descriptions.

Thus far it may be concluded that the eyes of Chilopods are more polymorphic and more complex than those of Chilognaths. Sograff says that the eyes of *Lithobius* and *Scolopendra* are quite like the eyes of coleopterous larvæ, as well as of spiders. They cannot, however, be thus compared with both of these, which Grenacher has shown to represent the two principal types of stemmata, respectively. The eyes of *Julus* and *Glomeris*, but not of *Lithobius*, have their soft parts disposed in one layer, and so far may be likened to the (monoderic) eyes of the young *Dytiscus*, or of the *Acilius*-larva. In the Scolopendridæ we are met by this difficulty—that the eyes of the same species, at different stages, may show two different structures; nor can it yet be said which of these two be the primitive.

Physiologically, the simple eyes of at least some Myriapods must be very unlike the ordinary stemmata of spiders or insects. These are true perceiving organs. In Myriapods, on the other hand, each stemma has its retinal elements, or their representatives, so disposed in regard to the axis of the cornea-lens, and therefore to the incident rays of light, that it seems very doubtful whether such eyes can do more than distinguish between degrees of light and darkness. Grenacher admits that this is a rather paradoxical result, when we consider the apparent waste of means involved [but is not in contradiction to the derivative hypothesis]. There is yet need of much exact work in this wide field of inquiry.

The eye of *Limulus*, already roughly compared by Grenacher with the Myriapod-eye, is now more closely affined to that of *Julus* or *Glomeris*, since it appears to be one-layered.

γ. Arachnida.

Poison-glands of Spiders.*—It has long been known that spiders possess a pair of glands, presumed to be venomous, opening by long excretory ducts at the free ends of the cheliceres. Dr. J. MacLeod has examined these glands in several spiders, and gives details of their minute structure.

The body of the gland consists of two layers, muscular and secretory. The muscles constitute a uniform stratum, resolvable into spiral bands, which are closely set and quite flush with one another because of their very regular thickness. Each muscular fibre has a pointed end, by which it dovetails gradually with its neighbour. Transverse striæ, often difficult of detection, seem always to be present. Numerous nuclei are deeply sunk in the muscular substance; these nuclei are disposed in longitudinal rows, of which as many as six in parallel lines have been counted in a single fibre. Regularly prismatic fibres, showing four sides in cross-sections, were seen in certain species.

An outer envelope of thin connective tissue, with nuclei here and

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* Arch. de Biol., i. (1880) pp. 573–82 (1 pl.).

there close to its surface, invests the muscles. This envelope is best observed in large spiders; in smaller species it shows no nuclei. Between the muscles and the epithelium lies a thicker connective tunic, from which extend septa, isolating the muscular fibres, to their exterior investment.

The secretory epithelium is monoderic. Its cells are cylindric or subconical, with smooth or slightly folded sides, and a little prolongation at their fixed extremity, near which is a round or oval nucleus. They present very striking differences, however, doubtless corresponding to their states of repose or activity. In what seems its state of rest, the protoplasm of the cell is mostly granular. In the opposite state, a clear substance accumulates towards the free ends of the cells. Such cells may appear caliciform, their free ends representing the duct found in unicellular glands. Dr. MacLeod distinguishes two other forms of secreting cells intermediate between these extremes. In some spiders the depth, as well as the transverse extent of the cell, varies much, giving a composite aspect to the gland in transverse sections.

The excretory duct of each poison-gland has no muscles in the smaller spiders, though the two connective envelopes remain. A trifling portion of the body of the gland adjoining the duct is also without muscles. In the larger spiders muscles of the duct are present. They display in the common house-spider a beautifully distinct transverse striation; but their outer connective envelope is very delicate, and has no nuclei. The epithelium is pavimental in this species, cuboid or subcylindric in the common garden-spider.

Supposed Stridulating-Organs of Steatoda guttata, Wider., and Linyphia tenebricola, Wider.*—Mr. F. M. Campbell draws attention to the presence, in the female of the former species, of organs similar to those of the male, which were originally mentioned by Professor Westring. In both sexes the apparatus consists of a strong chitinous socket at the base of the abdomen, into which the hinder part of the cephalothorax fits. In the male the socket is a complete ring, with some spurs on the inside of its external edge, which is also roughly serrated. That of the female is divided into two parts, the inferior being the smallest, while the superior, as in the male, is the deepest. The female has no spurs; the inner edge, however, is undulated, and at points angulated, while a little below are stiff hairs on small protuberances. The chitinous thoracic extension of the male is marked on its superior surface with many fine parallel transverse grooves, which are absent in the female; while in the same position on both sexes are several ridges, which are less numerous in the male.

The organs of *Linyphia tenebricola* are seated on the falces and palpi, and are common to both sexes. On the outer side of the basal joint of each falx, are about twenty parallel transverse chitinous bands, placed so that their inferior edges are free. The opposing surface is that of the humeral joint of each palpus, which is marked with a more or less regular series of curved grooves, deep enough to

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* Journ. Linn. Soc. (Zool.), xv. (1880) pp. 152–55 (2 figs.).

give the appearance of serration on its side under a $\frac{2}{3}$ objective. On the inside of this joint, close to its base, is a curved enlargement, and on the top a prominent, horny, knot-like plate.

Glands in the Maxillæ of Tegeneria domestica, Blackwall.*—These glands, which seem hitherto to have escaped notice, are also described by Mr. F. M. Campbell. Their apertures are on the inner side of the median line of the upper face of each maxilla, where they commence to incline towards the mouth. The external form consists of a ring, averaging in adults ·005 mm. in diameter, enclosing a raised disk, in the centre of which is the opening leading to a narrow cavity, from which runs the duct, gradually increasing in size until it terminates in an elongated bulbous point. Similar organs are found in some Linyphiidæ, Thiridiidæ, Salticidæ and Epeiridæ, but they are distributed at the side of the maxillæ close to the mouth in a cup-like cavity, as shown in a drawing from an *Epeira similis* Blackw. Some of the ducts often become chitinous. The number of glands increase with age. Mr. Campbell found one on the first exuvium of two species of *Tegeneria domestica*, two on the second, and 80 on an adult female of the same species.

δ. Crustacea.

Heart of Decapod Crustaceans.†—A detailed experimental study of the heart's action among the larger Crustaceans has been published by Prof. F. Plateau. With the aid of Marey's device, and the use of the recording cylinder in the Ghent Physiological Laboratory, he has obtained a valuable series of tracings by means of the graphic method. The form and structural relations of the heart are sufficiently explained. The movements of the heart are recorded as they occur: (1) in health, (2) when influenced by electric stimuli, (3) when exposed to changes of temperature, (4) in a state of asphyxia, and (5) under the operation of eight selected poisons. Running comparisons are instituted between the effects of these poisons in Crustaceans and Vertebrates, with the result of showing fewer discrepancies than has hitherto been supposed. The innervation of the heart, and the part played by the pericardium, are also fully considered. This memoir is quite indispensable to all workers in the same field. We can offer no abstract of its contents; the author's own summary covers six pages. Due references are made to other investigators.

Development of Fresh-water Macroura.‡—Dr. P. Mayer describes the first seven stages in the post-embryonic metamorphosis of *Palæmonetes varians*. He figures the more characteristic phases successively presented by the paired appendages, the fore-end of the carapace, and the telson; of the whole animal (bird's-eye or profile) views in four stages are shown. Without the aid of these figures his memoir could not be well epitomized. It must be studied in connec-

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* Journ. Linn. Soc. (Zool.), xv. (1880) pp. 155–8 (5 figs.).

† Arch. de Biol., i. (1880) pp. 595–695 (2 pls.).

‡ MT. Zool. Stat. Neapel, ii. (1880) pp. 197–221 (1 pl.).

tion with that of Faxon, on the development of *Palæmonetes vulgaris*,* and with Fritz Müller's preliminary notice of *Palæmon potiuna.*† An introductory account of the literature of *Palæmonetes* and allied Crustaceans is given by Dr. Mayer, who also notes at the end of his paper some general considerations of much interest.

The development of this fresh-water species of *Palæmonetes* is more like that of the fresh-water *Palæmon* than that of the marine *Palæmonetes.* As with *P. potiuna*, the embryo leaves the egg in a comparatively advanced condition, furnishing another instance of the abbreviated development so often observed in fresh-water forms when contrasted with their nearest allies found in the sea.

Dr. Mayer maintains, against Balfour, that Claus was right in rejecting the ingenious hypothesis of a palingenetic zoœa, first suggested by Fritz Müller. Putting the Cumacea and Arthrostraca aside, and admitting the common plan of the true zoœæ of crabs and Macrourous Crustaceans, Dr. Mayer does not believe that these Decapod-zoœæ and the very different pseudozoœæ of Stomopods and Schizopods had a common progenitor (in any near sense of that term). Granting their resemblances, these diverse zoœæ represent not a lapsed adult, but an ancestral larva. Again, the development of the Penæidæ strongly favours the view that the zoœa is really a cænogenetic form, the true relations of which to the *Mysis*-stage do not seem to have been rightly apprehended by Balfour.

Nauplius Form of Leucifer.‡—Professor W. K. Brook's observation on this Podophthalmate Crustacean are of considerable importance, owing to the fact that Fritz Müller did not raise the young of *Penæus*, but only inferred their relation from the observations due to collections made by dredging. We have now, however, absolute proof of the Naupliiform stage in one podophthalmate Crustacean.

The eggs of *Leucifer* are, it is very interesting to note, developed in what Professor Haeckel has called the archi-gastrula mode, a mode which, it may be remembered, is found, among others, in the simplest Vertebrate—*Amphioxus.* The *Nauplius* is not specialized and peculiar, as is that of *Penæus*, but is typical, and very much like that of a barnacle or of a *Cyclops.* The eggs of the highly specialized Decapod *Libinia* have been followed out in their development by Mr. Wilson, who finds that in them the record is so compressed that the zoœa when it leaves the egg has the full number of appendages. Some importance has been given to the skin shed by the zoœa, which has been regarded as being a Nauplius-skin. Mr. Brooks now shows that the Nauplius itself sheds a similar skin after leaving the egg.

Polar Globules in the Ovum of the Crustacea.§—Grobben is the only author who has hitherto noticed the presence of polar globules in the ovum of the Crustacea. He states that he saw, in the ovum of

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* Bull. Mus. Comp. Zool. Cambridge, U.S.A., v. (1879) No. 15.

† See this Journal, iii. (1880) p. 630.

‡ Amer. Natural., xiv. (1880) pp. 806–8.

§ Bull. Soc. Philom. Paris, 1880, April 10. See Ann. and Mag. Nat Hist., vi. (1880) p. 465.

Moina rectirostris, a small clear spot situated at the superior pole, enclosed in the vitellus, which he regards as a polar globule flattened by the envelope of the ovum which is closely applied to the vitellus.

On examining recently-laid ova of *Asellus aquaticus*, M. L. F. Henneguy saw, in the tolerably wide space which separates the vitellus from the chorion, two small transparent globules, containing a few granules, and presenting all the characters of the polar globules, observed in the ova of other animals. He also twice saw one of these globules detach itself from the vitellus. In all the ova examined these little bodies were nearly of the same diameter. In some ova there were four of them, forming a group, and they were then smaller than in the ova in which there were only two; it is probable that in this case the two globules had divided. These globules persist for some time in the ovum, and only disappear when the vitellus is already divided into about ten segments. The first segmentative grooves forming simultaneously around nuclei which make their appearance at the surface of the vitellus, the polar globules do not here play any part in relation to the production of the first segmentative furrow, and cannot be regarded as directive corpuscles. Their formation is very probably connected with the disappearance of the germinal vesicle, as Fol and Hertwig have demonstrated in the case of the Echinoderms; but the opacity of the vitellus has not allowed the author to see the germinal vesicle, or to witness its disappearance.

Vermes.

Development of the Polychætous Annelids.*—Some of the early stages in *Clymenella* and *Arenicola* have lately been observed by Mr. E. B. Wilson.

The eggs are found in transparent gelatinous masses which, in the case of *Arenicola*, may come to be five or six feet in length and two to four inches in diameter. No polar globules were observed. At the first cleavage the egg is divided into two unequal spherules; at the second the smaller spherule is divided into two equal and the larger into two unequal parts; next, four much smaller cells separate from the four blastomeres, and soon the micromeres alternate with the macromeres; the former now divide more rapidly, and ultimately grow over the macromeres, part of which do, however, as the writer believes, go to form part of the epidermis. The remaining macromeres form the endoderm; two larger derivates of the macromeres apparently form the primary mesoblasts. The mouth arises on the ventral surface, and nearly opposite the pole at which the first four micromeres appeared. The anus is formed at the posterior end. The egg-membrane is said to pass into the cuticle of the larva. During segmentation, periods of activity alternate with periods of repose. The larva is telotrochous, the setæ develop from before backwards, and those of the dorsal before those of the ventral ramus. The segmentation appears to be very similar to that of the Oligochæta and Discophora.

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* Amer. Journ. Sci., xx. (1880) pp. 291–2; Ann. and Mag. Nat. Hist., vi. (1880) pp. 407–8.

Mr. Wilson also states* the preliminary results of his investigations into the development of *Diopatra cupræa* and *Spiochætopterus oculatus.* The egg-masses of the former are cylindrical, and are 18 inches to 2 feet long; the larvæ are at first true Atrocha, with an anterior apical tuft and two reddish eye-specks; they have a close resemblance to the Eunicid larva figured by Claparède and Metschnikoff. The antennæ begin to appear when the larva has four setigerous segments. The latter species has the larva mesotrochal, and very similar to that of *Phyllochætopterus* (C. and M.); ten segments are developed before the branchiæ appear.

Ocnerodrilus: a new Genus of Oligochæta.†—Dr. G. Eisen gives a description of a species of Californian Lumbriculid, for which he forms a new genus, and to which he gives the specific name of *occidentalis,* which is at once distinguished from all its allies by the following characters, some of which would appear to be of even more than generic value.

The efferent ducts are not free, but are partly grown together, and there are no prostate glands; the ducts and the receptacle open at the same pore. There is no atrium, but there is a heart; the dorsal vessel is three-branched in front, but the ventral vessel is not forked.

After giving in detail the generic characters of this and of the other members of the family, the author raises, without settling, the question whether the new genus should not be placed in a new family or sub-family. As he justly observes, however, the characters of its organization are, for the time, of far greater importance.

The very muscular œsophagus extends through six segments, and for the first five of them it is surrounded by a pair of very large lobate glands, similar to but larger than those of *Enchytræus.* In the seventh segment the œsophagus is provided with two large sac-like appendages, of nearly the same structure as the œsophagus itself; these appear to be very characteristic. The "intestine proper," which is very much less muscular than the preceding portion, is divisible into two distinct parts; the anterior portion, which is much the broader, is covered with minute pigment-cells. The genus is further remarkable for the distinct differentiation of two pairs of hearts, situated in the eighth and ninth setigerous segments, and both communicating with the ventral vessel. What, however, is still more characteristic is the forking of the dorsal vessel, which in all other members of the family is "entire." Here, however, we find from the seventh setigerous segment forwards two lateral branches, in addition to the main trunk; these are connected one with another, and with the ventral vessel. Gastric and perigastric vessels are also present.

The segmental organs are found in all the setigerous segments except the thirteenth and sixteenth; in the former their place is taken by the oviducts, and in the latter by the efferent ducts, and by the receptaculum seminis. "The whole organ resembles more that of a *Limnodrilus* or a *Tubifex,* than those described as belonging to any genus of the Lumbriculidæ."

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* Zool. Anzeig., iii. (1880) pp. 455–6.

† Nov. Act. R. Soc. Sci. Upsal., x. (1879) Art. IV., 12 pp. (2 pls.).

Both margins of the supra-œsophageal ganglion are deeply emarginated; a distinct infra-œsophageal ganglion cannot be clearly made out. The first two ventral ganglia give off only two, but the rest give off three, pairs of nerves.

The sexes are united in the same individual, and the author's account of the male organs is, from a general point of view, extremely interesting, inasmuch as we have in *Ocnerodrilus* that permanent disposition of the testes which becomes so remarkably obscured in the earthworm. There are two pairs of testes, constantly minute in size; one pair is situated in the eighth segment, and is attached to the septum that separates that segment from the ninth; the second pair is attached to the anterior septum of the tenth segment. The largest spermatozoa are found nearest to the upper margin of the lobes; the smallest resemble the ovarian cells, and are found close to the dissepiment. The efferent ducts have no prostate glands, and further, also differ from those of other Lumbriculidæ by opening at the same segment and into the same pore as the receptaculum seminis; the pore is found in the sixteenth segment. The ducts are apparently, but not really, fused together. The ovaries are attached to the front face of the dissepiment which separates the eleventh and twelfth segments. No eggs are ever found floating in the body-cavity; the oviducts open on either side of the ventral line, and in the middle of the thirteenth segment. The receptaculum seminis is enormous, and extends backwards from the sixteenth as far as the twenty-fifth segment, or even further; it forms a long, narrow, thick-walled bag. No cloaca of any kind is formed at the genital orifice.

O. occidentalis is about 20 mm. long and 2 mm. wide; its colour is compared to that of raw meat. It is, unlike *Lumbriculus* or *Rhynchelmis*, exceedingly slow in its movements. It was found in Fresno County, California, and is said to be mature in the latter part of October.

Segmental Organs of Echiurida.*—These interesting structures are discussed by Dr. R. v. Drasche, who points out that the demicanalicular coiled spiral folds found by Greef in *Thalassema Mœbii*, may be referred (as the examination of a new species of *Thalassema* from the Island of Bourbon has shown him) to the funnel of *Echiurus Pallasii*, the lateral margins of which are produced into spirally coiled grooves. This modification of the funnel has also been detected by the author in a new Japanese species of the genus *Echiurus* (*E. unicinctus*). The grooves in question lead to the cleft of the funnel, shortly behind the edge of which there commences a narrow canal, which leads into the segmental tube.

Northern Gephyrea.†—D. C. Danielssen and J. Koren describe four new genera (*Hamingia*, *Saccosoma*, *Stephanostoma*, and *Epithetosoma*) and seven new species of Gephyrea obtained by the Norwegian North-Sea Expedition. A new family—Epithetosomatidæ—is pro-

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* Zool. Anzeig., iii (1880) pp. 517–19.

† Nyt Magazin f. Naturvid., 1880, pp. 44–66. See Ann. and Mag. Nat. Hist., vi. (1880) pp. 462–5.

posed by the authors. The depths varied from 70 to 1215 fathoms and the latitude from 63° 5′ N. to 73° 47′·5 N.

Organization and Development of the Gordii.*—M. A. Villot (in a second note) describes the atrophy of the digestive organs, and the development of the genital organs, and of some other systems. In the integument he can detect only two layers, one superficial, structureless, and not coloured; the other formed of connected elastic fibres more or less strongly coloured. The second or lower layer is not differentiated till towards the end of the second larval period. The author now explains how it is that the different parts of the nervous system are found in the adults to be continuous. In the larva of *Gordius* there is no cerebroid organ, but there is an œsophageal ring exactly comparable to that which is found in the Nematodes. When the œsophagus disappears, as it does in the adult *Gordius*, the nerve-centres unite into a cephalic ganglion. This important character appears to the author to be a sufficient justification for the formation of a special order for the genus *Gordius*, which would be intermediate between the "Helminthes" and the Gephyrea. There is always an extremely close connection between the epidermis and the nervous system. The general structure of the nervous system seems to be somewhat remarkable, inasmuch as the author states that, in certain conditions, it has the appearance of a true vascular system; water penetrates into it very easily; the cells of the hypodermic plexus dilate and become pyriform in shape, while the epidermis of the papillæ swells and becomes pushed out to the exterior. It is these processes which Von Siebold and the author have taken for parasitic algæ.

The development of the muscular system is simple. The myoblast loses its spherical and takes on a ribbon-shaped form; the envelope of the cell forms the myolemma, and the contents the contractile substance. This condenses against the cell-wall, and becomes divided into longitudinal fibrillæ, which run parallel to the long axis of the fibre. This mode of formation of the muscular elements is said to be most marked in the Polygordiida.

The atrophy of the digestive apparatus consists chiefly in the disappearance of the mouth of the œsophagus. The secreting organ described by Meissner is nothing but the intestine, which ends anteriorly by a delicate cæcum, and posteriorly by opening into the cloaca. Part of the parenchyma of the adult always retains the characters of the embryonic tissue, while the rest is converted into connective tissue or cartilage. The arrangement of these layers can best be seen in transverse sections of the female cloaca.

Nematoid Parasitic in a Bat.†—Dr. Macdonald gives an account of a worm, to which its discoverer—Dr. Dobson—has given the name of *Pterygodermatites* ‡ *Macdonaldi*. It was at first sight thought to be Annelidan,§ but Dr. Macdonald now recognizes its Nematoid character;

* Comptes Rendus, xci. (1880) pp. 774–6.

† Ann. and Mag. Nat. Hist., vi. (1880) p. 409.

‡ An older generic name is *Rictularia*.

§ 'Nature,' xxii. (1880) p. 583.

while Dr. Dobson is of opinion that it forms the type of a new order of Vermes intermediate between the Trematoda and the Rotifera. The following points would seem to indicate the Nematoid character of this endoparasitic form: the general form of the body is terete, the mouth is simple and subterminal, the regularly arranged leaflets are simply extensions of the integument, supported by chitinous fibres; there is no external or internal indication of any annulose segmentation of the body. The intestine is at first straight, then forms a sigmoid curve, and then after another short straight piece coils spirally round the spiral rachis of the ovary. There were 73 pairs of the lamellar processes.

Excretory Organs of Trematoda and Cestoda.*—M. J. Fraipont has a third note on this subject, in which he gives an account of his further investigations on the endoparasitic Trematodes of marine fishes and on a species of *Bothriocephalus*. Of the former, he says that he always found in it the ciliated infundibula. In the scolex of *Tetrarhynchus tenuis*, Professor Francotte has observed, and M. Fraipont confirms the observation, that in the young cystic stages when the scolex is hardly developed, there is, independently of the foramen caudale and the two large longitudinal trunks, a system of fine canaliculi terminating by ciliated funnels. In the complete scolex, while still encysted, the two longitudinal canals bifurcate and penetrate into it to form four longitudinal trunks; these form a complicated plexus in the head. In the *Scolex trygonis pastinaceæ*, which is especially suitable for these studies in consequence of the great transparency of the tissues, the two canals give off here and there lateral branches which traverse the superficial layer of the parenchyma, pass through the delicate cuticle of the body, and open directly to the exterior; both the larger and the smaller canals are contractile, and the author has been able to observe the expulsion of part of the contents by the lateral secondary orifices; the smaller branches are more numerous towards the anterior than the posterior region of the body.

Having described the arrangement in *Bothriocephalus punctatus*, the author concludes by observing that the fact that there is this secondary communication with the exterior for the renal apparatus, that there is a tendency to a symmetrical repartition of these orifices, that in *B. punctatus* they are found in each segment, and that this form has no terminal pulsatile vesicle, lead one to imagine how an excretory apparatus, primitively single in the lower Platodes, may be transformed into the arrangement seen in other and higher forms; into, that is, veritable segmental organs, independent of one another, and similar in each segment. But, as he justly observes, the developmental history has still to be worked out.

Anatomy of the Liver-Fluke.†—Dr. F. Sommer has an essay on this important and, at this time, peculiarly interesting form. The broad and flattened body of *Distomum hepaticum* has an oral orifice at

* Bull. Acad. R. Sci. Belg., L. (1880) pp. 265–70.

† Zeitschr. wiss. Zool., xxxiv. (1880) pp. 539–640 (6 pls.).

its anterior end. This region is somewhat conical in form, and the long diameter measures not more than from 3–4 mm. The larger hinder portion of the body varies greatly in proportional dimensions, owing partly to the different size which the uterus has at different periods. In the surfaces of the flattened body it is possible to distinguish two lateral from the broader median areæ; the former are brownish or orange in colour, and the latter is of a greyish yellow coloration, washed here and there by whitish spots, and having at certain points the coiled glands shining through. As is well known, there are two suckers, both of which are placed, not far from one another, along the middle line of the body. In addition to the oral and anal pores there is a third—the genital—which is placed on the ventral surface, and leads into a sinus genitalis, and a fourth, which is found on the dorsal surface, and which forms the termination of a canaliculus connected with the vitelline ducts.

For all practical purposes, at any rate, the fluke may be regarded as being acœlomate, so that the organs are all placed in the parenchyma of the body. This consists of connective and of muscular substances. The former is the most richly developed, and consists principally of cells, intercellular substance being but feebly developed. Owing to their close approximation to one another the cells very rarely exhibit a spherical form, and they are more commonly rounded polygonal, or laterally compressed. The muscular substance is formed of contractile, thin, elongated, homogeneous, non-nucleated bands, with dark contours after treatment with reagents. They are rarely single, and are ordinarily collected into bundles. It is difficult to say exactly where they have their insertion or their origin; it would seem, but the question is not settled, that they pass into the connecting substance, which unites together the contractile elements of the cortical layer.

When sections are made of specimens previously hardened in Müller's fluid it is easy to see that the body-substance is differentiated into two layers, median and cortical, and the differences between the two are exceedingly well marked. The cortical layer is not thick, as is the median, and this difference is to be ascribed to the absence in it of the supporting substance, and of all the more important organs of the animal. In this cortical layer, then, we can make out (1) the cuticle, (2) the outer or subcuticular cell-layer, (3) the dermo-muscular layer, and (4) the inner layer of cells. After giving a detailed description of these parts the author passes to the consideration of the structure of the suckers. In these we may detect a large number of contractile fibre-cells, which are set in three different strata or systems —equatorial, meridional, and radial.

In the parenchyma of the central or median layer we find (1) a well-developed digestive and an excretory apparatus, (2) organs for the circulation of the nutriment, and for the functions of respiration, (3) male and female reproductive organs, and (4) a nervous system, divisible into a central and a peripheral portion. The digestive tract extends by its terminal branches throughout the whole of the body-substance, and the blind ends of its branches come quite close to the margins of the body; the mouth is placed at the bottom of the anterior sucker, but has an anal in addition to an oral function; the ingestive and digestive regions of the interior are very distinctly marked off from one another. The œsophageal portion is well provided with muscle, and the whole anterior region is well adapted to act as a sucking organ. Protractor and retractor muscles are further attached to the pharynx. By the especial action of the latter the pharynx is filled, then the circular muscles of the pharynx contract, and the nutriment is driven into the stomach or digestive portion. This, which is at first unpaired, soon divides into two lateral branches, and from these sixteen or seventeen processes are given off. After describing the arrangement of these offshoots, the author proceeds to the histology of this part of the tract, in which he finds an outer layer of connective substance (a layer of contractile elements could not be observed, although Leuckart has reported its presence), and an inner layer of enteric epithelium, which is simple, and made up of cylindrical cells of varying heights. The characters which these cells present compel the author to compare them to the nutrient individuals of a Hydroid colony. A characteristic figure is given to illustrate their mode of seizing on the food, in which the irregular projection of their protoplasmic contents is very well shown.

Under the head of the excretory system the writer gives an account of a system which, not only in its physiological relations, but also in its structural characteristics, calls to mind the lymphatic system of the Vertebrata. This system does not, however, communicate with the hæmal, but passes its final or uric products to the exterior. It is, in fine, a system which, while it resembles by its characters and distribution the lymphatic system of the Vertebrata, differs from it, and resembles the excretory organs, in opening on to the surface of the body. The tubes can best be made out by filling the system which they compose with colouring matter, and this can be introduced by the excretory pore, or, still better, by injection. The system consists of the ducts in the tissues and the collecting vessels. The former especially arise in the substance of the median layer; the tubes unite into a collecting plexus, which is concentrated at the boundary between the median and cortical layers; the ducts given off from this anastomose and so form a second plexus. No valves, nor any layer of muscles with a special expulsive function can be made out in any part, or even in the terminal trunk. The tubes contain a colourless fluid with small refractive globules. According to Leuckart, guanin was detected by Lieberkuhn in the contents of these vessels.

The nervous system is very difficult to make out, owing probably, as Leuckart has suggested, to the absence of any perineurial investment. As an aid to research it is well to place the animal in carmine, then to treat it with alcohol, and finally to clarify it; sections must also be made. The central portion consists of a nerve-ring around the pharynx, which is enlarged at three points by the deposition of ganglionic cells. Two of these, which are bilaterally symmetrical, lie just behind the sucker, and form the supra-œsophageal ganglia; the third may be regarded as the sub-œsophageal ganglion. The two former are connected by a transverse commissure, and each is connected by a lateral band with the inferior mass, which is smaller in size as compared with the other two. So far as the author was able to follow the peripheral nerves from the inferior ganglia he found that they took an ill-defined peripheral course, remaining distinct from one another. Those from the supra-œsophageal ganglia took either an anterior or a posterior direction. Those of the latter set go principally to form the two lateral nerves, and they appear to send off branches to the viscera.

The author devotes a large part of his essay to an elaborate account of the structure and arrangement of the very extensive generative organs, as to which we can only say here that in the genital sinus the female orifice was found in the upper wall of the open end, and the male pore at the base of the sinus. The double testes are anterior or posterior, and are made up of a number of tubular glands. The male efferent apparatus consists of paired, elongate efferent ducts, which open into the unpaired cirrus sheath. The *ductus ejaculatorius* is provided with a number of appended glands. The female organs are, primarily, the yolk-glands and the distinct germ-gland; the latter is a ramified tubular organ of much smaller size than it is in *Tœnia.* The yolk-glands are placed in the lateral areas, and are the cause of the opaque or reddish colour of those regions; they, too, are compound tubular glands. The protoplasm of their cells gives rise to yolk-granules; these, set free, pass into the efferent ducts, break up into smaller parts and into a connecting substance, which latter unites the former into the yolk-spheres.

Monograph on the Cysticerci.*—M. R. Moniez, in his work on this subject, after an historical review, gives an account of his own researches. The first of these is on *C. pisiformis* (the "larva" of *Tœnia serrata*), which is found in rabbits; as to this he is in agreement with Professor Leuckart in believing that the different larval forms of *Tœniœ* (the *Echinococci* excepted) are developed on the same plan. What does this cysticercal form represent? At one time they were believed to be hydropic parasites, but since the time of Küchenmeister it has been recognized that they form a normal and necessary phase in the life-history of the *Tœniœ.* It is an asexual condition. Why is there exhibited the remarkable phenomenon of migration? Leuckart believes that it is due to the modifications arising from the fact that forms primitively confined to the non-vertebrated animals become the guests of the more lately developed Vertebrata. In opposition to this view, M. Moniez submits the following considerations.

The external parasites do not migrate; all the endoparasitic forms do. The reason is to be found in physiological and not in phylogenetic causes. The external parasite is submitted to a number of variations in the circumambient medium; the endoparasite lives a life of continual uniformity. Variations are necessary to existence; the parasite in the digestive tube lives in conditions which threaten

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* Travaux Inst. Zool. Lille, iii. (1880) 190 pp. (3 pls.). See Journ. de Microgr., iii. (1880) pp. 92–7.

it, so far, with destruction and degradation. Most especially does this affect the action of the reproductive elements on one another, and, where a joint of a *Tænia* does, as in some cases happens, fertilize itself, it is absolutely necessary for the young to undergo a complete change.

The author does not think that there is any alternation of generation in the Tæniadæ; he looks on the head of the *Tænia* as being merely an organ of fixation. The hexacanthid embryo forms the vesicle, but the produced scolex is not a new individual, but only a small part of the embryo, attached to the organ of fixation. All the vitality of the embryo being diverted to the formation of the head, the rest of the organism is unable to react against the influence of external forces, and thus, by endosmosis, it is penetrated by liquid matter. This liquid, accumulating in the central portion, disorganizes it, and in time causes it to perish. The cysticercus is, then, a young *Tænia;* the vesicle represents the first ring of the future chain; in most cases it disappears, without reproducing itself, after having served as an organ of protection. What we call the scolex is formed by the head (organ of fixation) and by a portion of the hexacanthid embryo, the rudiment of the future rings, which thus come to be situated between the first ring (the vesicle) and the head.

In an extract from his work,* he says, that the "head" is to be regarded as being morphologically developed at the hinder end of the animal; if this be so it is easier to compare their gemmation with that which obtains in the other Vermes.

It will be seen from this sketch that M. Moniez's views are not altogether those which have been hitherto regarded as explaining the history of the Tæniadæ.

Echinodermata.

Sexual Dimorphism in Echinoderms.†—Prof. T. Studer brings forward some evidence to show that the current opinion, which denies any sexual dimorphism to creatures of this group, is not altogether well founded. Investigators on Echinoderms of the Arctic and Antarctic seas have especially revealed a number of exceptions to the ordinarily accepted rule.

In cases where development is compressed we often find the young remaining for a long time under the protection of their mother. Long ago (1844) Sars observed cases of this kind in *Asterias Muelleri* and *Echinaster sanguinolentus*, and Daniellssen and Koren made (1856) somewhat similar observations on *Pteraster militaris.* Wyville Thomson has increased our knowledge as regards the Asterida, and Schultze and others have extended it to the Ophiurida (*Amphiura squamata*). Studer has himself described *Ophiomyxa vivipara* from the coast of Patagonia. The first to observe cases of this kind among the Echinoidea was Philippi (1845), and he has been succeeded by Agassiz, Studer, and W. Thomson. So again, Thomson followed Oersted in discovering viviparous arrangements among the Holothuroida. The cases cited fall under two heads—either the ova are developed within

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* Rev. Internat. Sci. Biol., vi. (1880) p. 135.

† Zool. Anzeig., iii. (1880) pp. 523-7, 543-6 (10 figs.).

or externally to the surface of the body of the parent. The Ophiuroidea are examples of the latter, as are the Echinoidea and the Asteroidea of the former of these two arrangements.

The simplest cases seem to be presented by *E. sanguinolentus* and *A. Muelleri*; here the arms of the starfish form a brood-pouch. In *Goniocidaris canaliculata* the ova are found in the anal area, where they are protected by the neighbouring spines. The same is the case with *Cidaris nutrix*. *Leptychaster Kerguelensis* has the body covered by paxillæ, the calcareous rods of which form a covering for cavities in which the ova undergo their further development. *Hemiaster cavernosus* is well known for the great depth of its posterior ambulacral grooves, in which the ova, covered by the marginal spines, lie protected. In the viviparous Ophiurids the ova are developed in enlarged bursæ, which open into the genital slits; these may be of an oval form and have their walls strengthened by calcareous rods.

It is clear that in animals provided with arrangements of this kind, the differences between the males and females must be such as to enable us to speak with a good deal of confidence as to the sex of the specimen in our hands.

The female of *Cidaris membranipora* has a flatter test, and the abactinal area is deeper and larger. The genital plates have a deep oval notch, which extends to the middle of the plate. "It is clear that by this arrangement the extrusion of ova, as much as 2 mm. in diameter, is considerably explained." The author next turns to the better known case of *Hemiaster cavernosus*, and then passes to the consideration of the Holothuroid *Cladodactyla crocea*, and *Psolus ephippiger*. In the former the female carries the young on the sucking feet of the dorsal ambulacra, which are considerably shorter than those of the ventral.

The female, then, in all these cases has secondary sexual characters, and they are always associated with the care of the young. It now remains to be seen whether differences ever obtain which are not due to this cause. Two examples are known to Professor Studer. In *Oreaster turritus* he has found two varieties which differ in colour, and the more or less dome-shaped form of the disk. With this difference was associated the presence in one of spermatozoa, and in the other of ova. A somewhat similar case is that of a new species of *Ophiothrix* (*O. Petersi*) from the West Coast of Africa.

Cœlenterata.

Diverse Nervous Susceptibilities of Lower Organisms.*—Two animals belonging to the same class, of comparatively simple structure, and therefore exhibiting morphological differences which to us seem trifling, may nevertheless display very diverse reactions when exposed to similar abnormal conditions imposed on them in the course of physiological experiments. In our attempt to explain the occult vital powers thus revealed, we are debarred from an appeal to the apparently corresponding diversities sometimes encountered in the case of the much

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* Krukenberg's 'Vergleichend-physiologische Studien,' Part 3 (1880) pp. 1–22 (3 figs.).

more complex Vertebrates. Two genera of Ctenophora, *Beroe* and *Chiaja*, have lately afforded Dr. C. F. W. Krukenberg an opportunity of further studying the difficult problem here in question. The effects of various mechanical injuries and poisons on these two gelatinous organisms were carefully noted. Atropin, helleborein, digatalin, and camphor exert little influence on either of them. Coniin, nicotin, physostigmin, quinine, &c., yield results which are not satisfactory. But most remarkable contrasts were discovered by using strychnine and curare.

A *Beroe* cut across so that six rows of combs were completely severed, two being left uninjured, was placed with one half in a solution of strychnine; the other moiety floated in pure sea-water, a stream of which also moistened the undivided isthmus crossing the edges of the contiguous vessels that contained these different fluids. The aboral* half, immediately exposed to the poison, showed the same phenomena as an unmutilated *Beroe* similarly treated; the combs ceased to act, contractions of the body-wall ensued, afterwards all movements stopped, and finally death occurred. After a pause of about ten minutes, the oral halves of the two uninjured meridians resumed the play of their combs, at first irregularly, subsequently with due regularity and persistence. The severed oral meridians were not affected. The combs of the isthmus, too near the poison, were brought to stillness. When the experiment was reversed, so that the oral half was immersed in the poisonous liquid, like changes were seen, except that resumption of their activity by the aboral halves of the rows of combs was regular from the first; the oral combs were at once deprived of motion.

Curare affects *Beroe* in a very singular manner. The combs not only come to rest, but are sunk in recesses of the meridians formed by the rising up on either side of the adjacent contractile wall of the body.

In *Chiaja*, on the other hand, we quite miss this curious retrocession. Curare, as well as strychnine, has little effect on this organism. Fragments of *Chiaja* show no pause or irregularity in the movements of their combs.

The formal differences between *Beroe* and *Chiaja*, which meet the eye of the comparative anatomist, do not help us in trying to account for such very notable constitutional pecularities. The much softer consistence of the general textures of *Chiaja* seems to furnish a more promising datum. There is little doubt that each locomotive comb possesses its own "automatic" centre. We must also assume separate centres for the meridional musculature, and these again are governed, inhibitorily or otherwise, by the conspicuous ganglion of the aboral region.

Dr. Krukenberg sets before us, in an ingenious diagram, what he believes to be the mutual relations of the *Beroe's* principal nervous centres. He expressly guards himself, however, against exaggerating the value of the sagacious hypothesis which he suggests, and concludes by reiterating his strong conviction that the essential complexity of

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* Read *aboralen* for *oralen* in text, p. 8, line 14.

vital actions, even in organisms far inferior to the Ctenophora, defies the present resources of physiologists.

"The changeful phenomena of life, which we remark in the smallest organisms—in the rhythm of their ciliary motions, now strengthened, now slackened; in the rhythmic alternation of the capacity of their contractile vesicles; in their regulated incomes, deposits, and expenditure; in the abundance of the visible products of their diverse material exchanges—enable us but remotely to foresee what is here effected by a harmonious co-operation of countless processes, limited to the smallest space. Let their formal differentiation seem to us ever so slight, just so do these beings become for us all the greater riddles, especially when we find in them vital manifestations elsewhere displayed in the living world only by apparatus of the most highly complex construction, and in them meet with processes which without the orderly co-operation of very different factors must remain to us unintelligible. Who would wish boldly to maintain, where even the most delicate methods disclose to us merely what is homogeneous, where quinine, in proportions scarcely perceptible by our nerves of taste, transforms the entire protoplasmic mass of an animalcule into an opaque albuminous particle, that the metamorphosis of tissue proceeds according to one chemical formula, that living protoplasm is a purely chemical substance, only excited and impelled by the elementary bodies and the rigidly associated combinations of the external world!"

Rising and Sinking of Beroe.*—According to Eimer, *Beroe* sinks by taking in more water than a vessel equal in capacity to the living animal could hold; the density of the liquid thus absorbed augmenting amid the interstices of its loose gelatinous tissue, as within a system of capillary tubes. But C. F. W. Krukenberg reminds us of Regnault's demonstration that a pressure of 200 atmospheres would only reduce the volume of sea-water by 1 per cent. Moreover, the living *Beroe* has a higher specific gravity than its environment. Its rising, not its sinking, is the real problem. Poisoned *Beroes* sink at once and stay at the bottom. Instead of repeating, with Eimer, that a *Beroe* freed from water floats like a dry sponge, we should say that the body, either of *Beroe* or of a dry sponge, must float when filled with air, as even platinum would do if it held air enough.

Krukenberg always found that non-vibrating *Beroes* remained below. He will not, however, doubt Eimer's observation, that these animals sometimes rest close to the surface of the water, with their vibratory lamellæ in absolute stillness. Like Eimer, he would account for this state of things by supposing an accumulation of gas.

"Completely sharing Eimer's interpretation that the vibratory lamellæ are truly such, but seeing that their movement is followed, at one time by a rise, at another by an accelerated sinking of the *Beroe*, one can only guess and is scarcely able to say what observations will decide this question, the answer to which no experimenter

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* Krukenberg's 'Vergleichend-physiologische Studien,' Part 3 (1880) pp. 147–50.

has yet given. New methods must be found for our attempts to explain how the *Beroe* can thus shift its position."

Zoantharia of the Gulf of Marseilles.[*]—After shortly describing the local distribution of the chief Zoantharian forms in this district, M. E. Jourdan proceeds to deal with their zoology, histology, and development.

Under the first heading, besides many well-known British species, there is described a species without chromatophores, and therefore assigned to the genus *Paractis* as probably identical with *Actinia striata* of Risso; also a *Sagartia* new to science (*S. Penoti*), occurring either small in size and dull in colours, or large and brightly tinted. The well-known *Sagartia parasitica* is referred to *Actinia effœta* Linné, under the generic name *Calliactis* Verrill. *Phellia* (*Actinia*) *elongata* Della Chiaje, appears to have been recently found also in Dalmatia. *Ilyanthus Mazeli* is described as new, from 60 to 80 metres depth. *Palythoa axinellœ* is found on Algæ as well as on sponges; a new species (*P. Marioni*) of the same genus is described, from sponges and Serpula-tubes, from a depth of 110 metres; the columns are from 15 to 18 mm. high; colonies consist of but three or four individuals each, they are transparent, and of a very pale rose-colour. No *Edwardsia* occurred. Of sclerodermic corals were obtained *Caryophyllia clavus*, *Paracyathus pulchellus*, *Flabellum anthophyllum*, *Cladocera cœspitosa*, *Balanophyllia italica* and *regia*.

In the second part (*Histology*) the methods of study are stated to have been: (1) Observation of the living tissues: this was found especially useful[†] in distinguishing cilia from cnidocils. (2) Immersion in ½ per cent. osmic acid followed by absolute alcohol was found on the whole the best plan for hardening; hardening in osmic acid alone and mounting in glycerine were also found effective. Weak chromic acid solution or chromic and osmic acids mixed (Fleisch's recipe) were successfully applied to the hardening of small pieces by their immersion in them for two or three days. Larvæ were treated somewhat similarly. Picrocarmine and hæmatoxylin were found the best staining fluids. (3) Dissociation, for which a month's maceration in a ½ per cent. solution of ammonia bichromate, or in very weak solutions of chromic acid, was a good preliminary step. Sclerodermic corals were first decalcified with picric acid.

The results thus discovered in various species are as follows:—

Anemonia sulcata (*Anthea cereus* of Gosse).—The *tentacles* have a slightly striated ectoderm, in which no distinct layers were made out, but when hardened it is found to be covered externally by a layer formed of the cilia agglutinated by mucus; at its true surface lies a layer of thread-cells, which sometimes occur without the coiled thread; similar cells occur deep in the layer. The thread-cell originates in a small, generally oval, cell provided with a basal prolongation; it appears first as a small rod lying beside a large nucleus among the granular protoplasm; it ultimately comes to be the only thing

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[*] Ann. Sci. Nat., x. (1880) Article No. 1, 154 pp. (17 pls.).

[†] Cf. a contrary opinion, this Journal, iii. (1880) p. 451.

occupying the cell, and then consists of a basally barbed thread and an apparently chitinous capsule with no protoplasmic contents. Glandular cells also occur in the ectoderm here, as fusiform or cylindrical bodies, sometimes bilobate, extending from the surface of the ectoderm,—where they open,—to the mesoderm, with which they have contact by a basilar process, usually swollen at one point; they vary considerably in appearance, being sometimes empty and hyaline, but generally more or less granular; they were found more abundantly in this species than in any other. Peculiar to this species, were found some very delicate fusiform cells, terminating in some cases in a fine cone; they are compared with the cells described as sensitive by Korotneff from the chromatophores of *Actinia mesembryanthemum.* Internally, the ectoderm is lined by a mesodermic membrane which appears structureless in osmic acid preparations; in transverse sections it exhibits processes which penetrate the ectoderm at intervals; in longitudinal section its outer border is unbroken; after treatment with alcohol it may be dissociated into fine connective tissue fibrils; it is probably an elastic membrane. The mesodermic muscles consist of an external longitudinal, and an internal circular set; their fibres are indistinguishable from those of the fibrous tissue. The endoderm, which is as thick in this species as the ectoderm, is formed apparently of two layers, that of the ciliated cells and a pigmented layer, but they are not really distinct; for the large and remarkably abundant pigment-corpuscles are arranged in single series in long tubular cells, extending from the free surface, where they terminate in cilia, to near the mesoderm; here, however, the pigment-globules of the cell, which are orange-coloured, well defined, and stain black with osmic acid, are replaced by a finely granular protoplasm with a nucleus. The contraction of one tentacle when pinched, without any participation in the movement on the part of the rest, seems to the author to show the absence of a central nervous system.

Buccal Disk and Œsophageal Tube.—Of the three layers which are present here also, the ectoderm of the disk agrees essentially with that of the tentacles; but as it approaches the lip the thread-cells diminish in number, and a form of gland-cell appears, which is only found elsewhere in the œsophagus. The passage to the ectoderm of the œsophagus presents no sharp line of transition in characters. The mesoderm is more distinctly fibrous, and its nuclei more evident in the disk than in the tentacles; it has a festooned inner border, the result of circular folds in it, which are lined by a layer of fine muscular fibres. The endoderm agrees with that of the tentacles. The œsophageal tube is thrown into regular longitudinal folds, of which each consists externally of ectoderm, and internally of a fibrous mesodermic process, which is continuous with a septum on its internal aspect, and ends freely in a mesenteric filament below; in its ectoderm are found sensitive cells, but almost no thread-cells or glands, the latter of which are here replaced by cells containing protoplasm which stains deeply with osmic acid. The mesoderm agrees with that of the disk, but is looser in the folds above mentioned, and becomes very thin in the spaces between them. The endoderm here is devoid of pigment-corpuscles; it is extremely delicate, for it often falls into a pulpy condition during treatment.

Body-walls.—The layers have the same general arrangement here. In the ectoderm, however, thread-cells are very scarce, and the glands are represented by clear spaces; the layer appears to consist chiefly of numerous fibrils set at right-angles to the surface, and dilated at one or more points. The mesoderm and endoderm agree with those of the disk. The mesenteries consist of strips of mesoderm, coated on each surface by a longitudinal muscular layer, and this in turn by endoderm. The reproductive organs originate in a kind of fold of the mesoderm. The sexes are distinguished by differences of coloration.

Actinia equina (*A. mesembryanthemum* of Gosse): *Tentacles.*—Of the three fundamental layers, the ectoderm has its outer surface thickly set with cnidocils; below these are numerous thread-cells. *Body-walls.*—Their thickness varies with age; thus, in a small adult, the ectoderm and mesoderm together measure ·085 mm. in diameter, in a larger one ·6 mm. The ectoderm differs from that of the preceding species in having ciliated cells much expanded at the free end, and a deep fibrillated layer from which may be separated granular, nucleated, "epithelio-muscular" cells, provided with a singly or doubly pointed basal fibril, and resembling closely those of *Hydra;* in the tentacles they are much more distinct, club-shaped, and connected with the fibril, which is here very short, by a peduncle. In some cases they have one or two dilatations above the fibril. The writer will not admit the distinctively nervous function of any of these cells, but regards them as having joint epithelial and sensory functions, and as sometimes giving origin to muscular fibres. The gland-cells of the layer have a basilar process. The mesoderm and endoderm present the same characters as in *A. sulcata.*

Chromatophorous Saccules.—Korotneff's chief results are confirmed. Some elongated elements terminating in a kind of cup at the free surface occur among the densely set external thread-cells; the thickenings seen at various points of their lengths are really dilatations of the cells, and not extrinsic to them. The usual granular band at the base of the ectoderm is here wanting. In a few sections the mesoderm exhibits nucleated cells. Though Korotneff found no connection between the thread-cells and cnidocils, the former are now found to originate each in a small protoplasmic mass at the external end of a cnidocil cell, much as in *Lucernaria.* The ordinary ectodermal glandular cells may have a basal hyaline process, but some elongated cells, doubtfully granular, also occur here, ending on the surface by a globular body, and bearing in their course dilatations, whose contents are hyaline vesicles, not affected by colouring reagents, but resembling adipose globules. The main function of the saccules is probably sensory.

Œsophagus and *Mesenteries.*—Not essentially different from those of other Zoantharia.

The *Sexes* are distinguishable by the brighter colour of the testes as compared with the ovaries; the former constitute a single series in the mesoderm of the mesentery, and consist of a fibrous membrane lined by a layer of endodermic cells; they contain one or more layers of round or somewhat angular cells; the spermatozoa appear as a granular mass, and develop at the expense of the lining cells. There is no permanent duct, but a temporary invagination, followed by rupture, of the fibrous coat takes place at one point. The mesenteric cavity is often occupied by some numbers of a species of Infusorian, provided with a series of oblique, raised, ciliated bands.

Bunodes verrucosus (*B. gemmacea* of Gosse): *Tentacles.* — A granular supra-mesodermal band contains some cells regarded as vibratile, and provided with basal nucleated processes formed by the cell-wall, connecting them with the mesoderm. This tissue consists of longitudinal bands exactly resembling the connective tissue of higher animals.

Body-walls.—The small warts of the column consist entirely of ectoderm, and like the oval hyaline spaces of the surface their elements are glandular cells, of which two types may be distinguished: the one club-shaped, strongly granular, not nucleated; the other, less abundant, is saccular, with an opening to the surface, with hyaline contents and nucleus. The glandular warts thus constituted originate in folds of the ectoderm as conical elevations of that tissue, which sink into the mesoderm, lose their ciliated cells, and become more or less shut off from the ectoderm, which closes round their sides; their function is to secrete mucus. The rest of the ectoderm consists of elongated, ciliated cells, in addition to the glandular ones found in the warts. The mesoderm is made up of an external, bilaminate, fibrous, and an internal muscular layer; the external layer consists of loose connective tissue, the inner one of wavy laminæ, indented by circular folds. The endoderm-cells are delicate, and contain fatty globules.

Mesenteries.—They may be studied with unusual ease in this species by sections. They present a number of deep folds on one of their sides. The *foot-disk* has a special contractile layer, consisting of radiating fibres; these, with the ordinary circular muscles and fibrous tissue which is connected with that of the mesenteries, constitute the apparatus which fixes the animals.

Corynactis viridis: Tentacles.—The terminal knob is due to the superior thickness at this point of the ectoderm, which in the tentacles is mainly composed of thread-cells, with a few cnidocil elements. *Body-walls* almost entirely made up of glandular cells; a few elongated cells, perhaps ciliated, also occur, and some thread-cells in which the filament is irregularly rolled up, and which are the largest found in the *Actiniaria.*

Sagartia Penoti.—The male organs resemble those of *Actinia mesembryanthemum* in the relations of the testes and their method of discharge. The observations of Heider on the genus are confirmed as to all other points.

Calliactis effœta (*Sagartia parasitica* Gosse): *Tentacles.* — The epithelial elements of the ectoderm are remarkably varied, and include club-shaped forms, forms with a basal fibril, and others, probably sensory, which are constricted above the nucleus, and thence produced into a terminally dilated tongue; larger glandular cells also occur here, and small scattered epithelio-muscular ones. The longitudinal muscles are composed of extremely long fibres, which, owing to their possession of numerous nucleated prominences on one side, must be regarded as compound, and as such are termed *pluricellular;* they are also found in the mesenteries of *Phellia.* Nervous elements are recognized in certain fine nucleated fibrils; they form a diffuse plexus at the base of the ectoderm, connecting the epithelial with the muscular elements, and must be regarded as putting these two sets of cells in communication; they resemble those found by Claus in the Medusa *Charybdea.* The *œsophagus* differs from the body-walls by the possession of glandular cells.

Body-walls.—The peculiar firmness of the column is due to the mesoderm, which, in section, resembles hyaline cartilage. The ectoderm consists solely of fusiform cells, without cilia, closely pressed together; they end externally in conical points. The mesoderm consists mainly of fibrous tissue, less dense the nearer it is to the summit of the column; the fibres have a vertical direction; there are two layers, the internal of which is regularly laminated, the outer not so; at the upper part of the column circular muscular fibres appear in this fibrous tissue, and increase in number, till at the summit they constitute its entire thickness. Longitudinal muscles occur as usual on the internal aspect of the mesoderm. The development of muscles within the mesoderm to this extent separates the genus distinctly from other genera, and explains the energy of the contractions of the body. The basal pores for emitting the mesenteric filaments are the outer ends of simple tubes, provided with a cellular lining but no special muscles.

The *foot-disk* secretes a viscous mucus, which aids in fixing the animal. *Mesenteries.*—Several orders are recognized, a fact interesting with regard to the connection between the soft and stony Zoantharia. There are two kinds of filaments; those with cilia are never emitted by the pores, the others consist of an external layer of thread-cells, a subjacent granular layer, and a fibrous axis which connects them with the mesentery, and is readily severed by contraction.

The chief point worthy of notice in *Adamsia palliata* is the large size of the male glands.

Phellia elongata.—The ectoderm of the tentacles has, beside glandular cells and nematocysts, a variety of epithelial forms, some possessing basal filaments, which differ, however, from those of epithelio-muscular cells, and resemble those in the Medusæ called nervous by the Hertwigs. The ridges of the body-walls are formed of ectoderm and mesoderm; the former is very thin and marked by a coat of mucous matter containing foreign materials, and consists of the same elements as the tentacles, substituting true muscular cells for those of possibly nervous origin. The mesenteries are remarkable only by the great development of the muscles, which form a large longitudinal band along one side of each mesentery; they have generally the peculiar characters of the tentacular muscles of *Calliactis;* they also exhibit waves of contraction. The reproductive organs lie at the bottom of the mesenteric cavity; the ovaries are winding bodies containing the slightly granular ova in the middle of their mesodermic layer.

In *Ilyanthus Mazeli* the mesoderm contains among its delicate fibres some large and very distinctly nucleated cells, giving the whole the appearance of fibro-cartilage.

Cerianthus membranaceus (*C. Lloydii*, Gosse).—In the *tentacles*, which carry numerous thread-cells, the mesoderm has an internal circular muscular layer, a middle layer of very fine fibres, probably nervous, and connecting the former with the ectoderm cells, and an external longitudinal muscular layer. The tentacles of the inner cycle differ from the rest, by the fact that glandular cells of peculiar structure enter into the composition of the ectoderm; their protoplasm is broken up into closely packed granular matters; some others are smaller and racquet-shaped. To the muscular fibres are laterally attached nucleated cells, so that they resemble the pluricellular fibres noticed above.

Œsophagus.—The ectoderm is most like that of the inner tentacles, but differs in having fewer thread-cells.

Body-walls.—The usual three layers are to be alone distinguished. The mesoderm differs from that of other Actinians, by having a special longitudinal muscular layer, which may attain a thickness of 2 mm.; the fibres become plicated during contraction. The ectoderm consists of a single layer of long fusiform cells, constricted at one or more points. The development of thread-cells may be traced from the simple epithelial form through a racquet-shaped to an oval stage; the inferior end is lost in the granular layer, the superior forms a tube leading to the exterior. The delicate fibres which traverse the granular basal layer of the ectoderm in all directions are probably nervous. The endoderm is exactly like that figured by Claus from *Halistemma tergestinum;* the cells are long, delicate, enlarged, and ciliated at the free ends; glandular cells also occur, differing from those of other Actinians, each being divided into a number of distinct portions, with a common nucleus and thin cell-wall, both of which may be lost. The *genital laminæ* are formed of a median connective tissue band covered on the sides by glandular and ciliated cells. In June the ova and male elements are found in a fold of the median layer. The male vesicles simply burst when mature.

Cladocora cæspitosa agrees with *Balanophyllia regia* in the characters of its cellular elements. In the latter species the *tentacles* have the fundamental characters exhibited in all the Zoantharia; the ectoderm is densely beset with cnidocils and cilia, and below them lies a dense zone of nematocysts, from whose bases long fibrillar cells run inwards; there are no glandular cells.

The longitudinal muscular layer is thin. The mesoderm has neither fibres nor nuclei. The endoderm consists of long granular cells. The ectoderm of the *œsophagus* consists of closely packed fibrillar cells, terminating in long cilia.

Body-walls also resemble those of the Malacodermata. Among the ectodermal cells of the upper part of the column are large, club-shaped, usually empty, ones, probably glandular; below these lie oval, granular cells, staining deeply with osmic acid; they are also found in the endoderm and in the septa. At the base of the column the gland-cells are absent, the pigment-cells less numerous; fusiform ciliated cells, probably nervous, and a few thread-cells, form almost the whole of the ectoderm. *Mesenteries* mainly as in Malacodermata.

Embryology of the Zoantharia.—Lacaze-Duthiers' conclusions as to the development of the mesenteries are confirmed; the so-called mesoderm is derived from the ectoderm.

In *Actinia equina* the axis is the only part of the mesenteries derived from the ectoderm. The gastrula is formed by invagination, and consists of two layers of large cells; the ectoderm-cells become smaller and fusiform, and the alimentary canal is formed by a kind of secondary invagination, the edges of the gastrula mouth being turned inwards and downwards into the cavity, which becomes filled with large vitelline masses. At a later stage the condition, especially as regards the mesenteries, corresponds with that given by Kowalevsky for *Alcyonium palmatum;* a distinct band (*membrana propria*) separates endoderm and ectoderm, from the former of which the mesenteries are derived. The mesoderm is differentiated from a granular zone which is formed at the base of the ectoderm.

Cerianthus membranaceus.—In four-tentaculate larvæ, the filamentous bodies noticed by Kowalevsky were observed, and considered to be mesenteric filaments. A *membrana propria* separates the endo- and ectoderm.

Balanophyllia regia.—The vermiform new-born larvæ float or swim rapidly; the costæ appear soon after birth. At the earliest free stage there is no *membrana propria;* it is found in six-tentaculate larvæ; the endodermic cells are large, and contain great hyaline vesicles, especially those in the centre of the body-cavity. The œsophagus is formed by the invagination of the ectoderm into the endoderm. The mesoderm arises as in *Actinia equina.*

Histological conclusions.—The author finds that the ectoderm of the tentacles varies little in the Actinians, owing to the constant presence of thread-cells interspersed with cnidocils, but that of the body-walls varies considerably; a granular basal zone containing nerve-fibres is a constant feature of it throughout. The endoderm is remarkably simple, and scarcely differs from that of the larvæ. The cnidocil-elements differ from ciliated cells only by the absence of cilia; they occur in Sclerodermata and in most Malacodermata, most abundantly in the tentacles. The ordinary ectodermic glandular cells differ from those of the endoderm by the granular character of their contents; they empty by rupture of the cell-wall; a hyaline form of gland-cell also occurs in the ectoderm in some species. The pigment-cells may be found in either of the three layers. The sensitive epithelial cells, which occur widely in the group, consist essentially of a fine fibril; the thread-cells are intimately connected with them. There are three types of the latter: (1) fusiform, with threads spirally rolled—the most common, found in all the species; (2) larger, with winding threads, peculiar to *Corynactis*, *Cerianthus*, and the Sclerodermata; (3) without thread, but with a spirally barbed rod. *Cerianthus* possesses all these forms. The muscular cells have always more or less the characters of epithelio-muscular cells, that is, of smooth, homogeneous, fusiform fibres without nucleus, united to a cell. The connective tissue varies from a finely fibrous condition to one in which the cells are large and distinct, recalling the characters of fibro-cartilage. The muscular system supplies no longitudinal muscles to the body-wall in Actinians, and it varies little in them; but in *Cerianthus* the longitudinal muscles are present, and constitute that genus a distinct type. No central nervous system was found; but nervous cells and fibres occur, and are especially abundant in *Calliactis*. The origin of the mesoderm from the ectoderm is established.

Structure of Corals and Sea-anemones.*—The brothers Hertwig have concluded, from their studies of *Actiniæ*, that the non-Alcyonarian Anthozoa (= Zoantharia of De Blainville and of Milne-Edwards, or Helianthoidea of Latreille) should not constitute a single order, but ought rather to be subdivided into several groups, each equivalent to Ehrenberg's Octactinia. As an important character, to be used for such subdivision, they suggest the structure and orientation of the mesenteries, with their associated muscles and genitalia.

Herr G. v. Koch continues his previous researches on the same subject. He first gives a revised list of the few groups in which the arrangement of the mesenteries is precisely known, and adds the following new observations:—1. In *Caryophyllia cyathus* the mesenteries and their muscles behave as in the ordinary Actiniæ. Of the stony septa, the older lie in the chambers, the younger are interlocular. The "ventral" septum usually differs from the "dorsal" in size. The same is true of the composite Aporosa, e. g. Stylophora. 2. *Madrepora variabilis* resembles Caryophyllia as to the arrangement of its mesenteries and muscles. The terminal calices had six septa within the (six) principal chambers, and six smaller interlocular septa; these last were absent, as a rule, in the lateral corallites. The dorsal and ventral chambers answer to the two larger tentacles. The two corresponding septa, which lie in one plane, tend to coalesce. 3. *Zoanthus* (*Palythoa*) *axinellæ* displayed the same (which we now, therefore, term the typical) orientation of the muscles. Koch's specimens had usually thirty-two mesenteries. Of these, eighteen bore filaments, and were inserted by their whole length along the alimentary vestibule, whose upper region only gave support to the other fourteen mesenteries, which were furnished with a free unthickened margin throughout the rest of their course.

Koch has also re-investigated *Cerianthus*. Young individuals of *C. membranaceus* displayed marginal tentacles so differing among themselves in size as to suggest a law of succession for these organs similar to that already noted by A. Agassiz. The marginal tentacles of the same species of *Cerianthus* are also furnished with curious longitudinal fissures. Each tentacle has a series of these fissures disposed on its inward (= axial) aspect. The fissures can be seen with the naked eye. A single fissure is placed midway between every

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* Morph. Jahrb. (Gegenbaur), vi. (1880) pp. 355–61 (1 pl.).

two of the dark ring-like patches which are particularly conspicuous along the tentacles of a variety of *C. membranaceus* found by Koch at Messina and chosen by him for the study of the openings in question. Water is abundantly discharged through the openings, whose alternate changes of form attest the contractility of their margins.

Structure of Cladocoryne.*—*Cladocoryne floccosa*, discovered at Herm, one of the Channel Islands, by Mr. W. D. Rotch, was referred in Allman's monograph of the Tubularians to a separate family, because of its exceptionally compound tentacles. Nothing was then known of its gonophores.

A second species of the same genus, *C. pelagica*, from *Sargassum* in the Gulf Stream, was subsequently distinguished by Allman,† who examined only preserved specimens and conjectured that the gonophores were phanerocodonic.

Rotch's species has again been found, near Naples, and Prof. G. du Plessis, working at the zoological station, has redescribed and figured it. He observed many histological details not noticed by his predecessors.

The Mediterranean specimens were never found on stones, but on Sertularians or sea-weeds. They showed a certain mimetism; brown or orange hydranths distinguished the stocks which frequented *Cystoseira* of corresponding tints, while various shades of red marked the individuals attached to diverse Florideæ. These colours are due to the presence of oil-globules within the flagelliferous cells of the gastric endoderm. The cells in question, as with some other Cœlenterates and Turbellarians, feed amœba-wise on the particles of the Copepods which the hydranth devours. The tentacles are not so irregularly scattered as would at first appear, but are disposed in approximately decussating circlets of four, somewhat as in *Cladonema* or *Stauridium*.

But the most noteworthy item in this new description refers to the gonophores of *Cladocoryne*. Sexual specimens, dredged from a depth of 30 metres, were forwarded to Professor du Plessis, after his departure from Naples, by Dr. Lang (librarian to the station). These were secured in June. There is now no doubt that the gonophores are not Medusæ, but sporosacs. They are inter- (not intra-) tentacular, placed between the verticils so that each occupies the centre of the lozenge constituted by four tentacles (two of which belong to each contiguous verticil). The male capsules, observed at all stages of maturity, were oblongo-ovate, on short stalks, and delicately rose-coloured. Their essential products seem obviously developed from the ectoderm. The ovarian sporosacs, shorter in form and deeper in tint, were more opaque. But two female individuals were seen. In the case of both males and females, sexual are smaller than neutral individuals. As the gonophores ripen, the tentacles of the supporting hydranth lose their branches, and, becoming shorter, eventually disappear. In this manner atrophied reproductive hydranths (= gono-

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* MT. Zool. Stat. Neapel, ii. (1880) pp. 176–96 (1 pl.).

† Journ. Linn. Soc. (Zool.), xii. p. 255.

blastidia) are developed. comparable with those which we find in *Eudendrium*. Professor du Plessis would place the family of Cladocorynidæ immediately after the Corynidæ (of Allman).

Porifera.

Sponges from Naples.*—Dr. C. Keller describes and figures on two beautiful plates four hitherto unknown sponges from the Gulf of Naples. *Rhizaxinella* n. g. is allied to *Axinella* O. Schmidt. The proximal (basal) end of *R. clavigera* n. sp. is rounded, but is fixed in its place by a tuft of root-like processes (*Wurzelschopf*). The cylindrical, somewhat prolonged, cœnosarc has itself no canal-system, is dichotomously branched, and ends distally in a small number of club-shaped, slightly constricted zooids, each with its terminal osculum. The young zooids are spheroidal, without oscula. In a specimen about six inches high, with six zooids, one of these showed two oscula.—*Cribrella labiata* n. sp. is remarkable for its sharply limited pore-areæ, whose elevated protrusible lips, when the sponge is disturbed, can almost be brought into contact.—*Tuberella* n. g. resembles *Tethya*, but has no stellate spicules. *T. tethyoides* n. sp. is curiously like *Tethya lyncurium*, and obviously differs in colour (both of its interior and exterior), as well as in form, from *T. papillata* n. sp.

In a supplement (pp. 280-282) to the preceding paper, O. Schmidt briefly describes, from the same region, *Stelletta carbonaria*, *S. fibulifera*, and *Tethyophana silifica*; the last of which is so close to *Tuberella tethyoides* of Keller, that it might be placed in the same genus. Two other "new" Neapolitan sponges (*Plicatella villosa* and *Phakellia plicata*) have been placed in the museum of the station by O. Schmidt, who also notes two interesting forms from Marseilles allied to or identical with Keller's *Rhizaxinella*.

Both Keller and Schmidt show that the sponge-fauna of Naples, while nearly related to that of the Adriatic, is further enriched by the presence of Atlantic species or genera.

New Group of Siliceous Sponges—the Plakinidæ.†—In his ninth contribution Professor F. E. Schulze deals with the lately discovered forms which he groups under the head of the Plakinidæ, and makes also some important remarks on the general morphological conclusions to which he has been led by the study of the development of *Plakina monolopha*.

In a simple saccular stage of development he detects three distinct concentrically disposed layers of tissue, which may well be regarded as ectoderm, mesoderm, and endoderm. Now arises the question, what parts arise from these three layers? Ganin, who has recognized a similar disposition in a *Spongilla*, thinks that the endoderm of the larva forms the thin unilaminate investment of the inner surface of all the internal cavities (the "body-cavity" excepted), as well as the outer surface of the various mesodermal septa. The endoderm only

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* Arch. Mikr. Anat., xviii. (1880) pp. 271–82 (2 pls.).

† Zeitschr. wiss. Zool., xxxiv. (1880) pp. 407–51 (3 pls.).

forms the outer layer of the integument of the adult. Keller thinks that the endoderm, in addition to forming part of the investment of the ciliated chambers, as Ganin allows, forms the whole of the flattened epithelial layer which forms the inner surface of the whole of the gastric cavity. Both Keller and Ganin believe that the whole of the mass of connective substance arises from the mesoderm. Led by further observations to depart from the views which he once held, Schulze now expresses his opinion that not only the collar-cells of the so-called ciliated chambers, but the rest also of the flattened flagellate epithelial cells are to be regarded as arising from the endoderm of the larva; or, in other words, two different series of cells owe their origin to the primitive endoderm, and the parts thus formed clothe, in addition to the ciliated chambers, all the cavities, ducts, and canals which arise from them, as far as the margin of the oscula. So again we find that the layer of flattened epithelial cells, which invests the free surface of the sponge (at any rate of *P. monolopha*), and lines its clefts and canals, is ectodermal in origin; it follows from this that the ectodermal and endodermal layers meet one another at two points, namely at the orifice of the ciliated chambers and around the edges of the oscula. The intermediate tissue would seem to arise from the mesoderm.

The Plakinidæ may be defined as Tetractinellidæ with isolated spicules (or with spicules not connected by a horny substance). The spicules may be bi-, tri-, or quadri-radiate, but they would appear to arise primitively from quadriradial spicules. Three genera are included, *Plakina*, *Plakortis*, and *Plakinastrella*, with three (*monolopha*, *dilopha*, *trilopha*), one (*simplex*), and one (*copiosa*) species respectively, so far as is yet known. All these forms exhibit points of striking resemblance in the histological details of their body-substance. The great development of highly refractive granules in the region of the ciliated chambers, in *Plakortis* and *Plakinastrella*, are points in which these two genera differ from *Plakina*, although there are indicatious in this last genus of this structural character, and, indeed, after all, we have rather to detect a gradual increase in the number of these granules as we pass from *Plakina monolopha*, through *P. dilopha* and *P. trilopha* to *Plakortis simplex*. The author proceeds to point out the relations exhibited by the spicules.

Some points in the characters of the different species may be noticed. *P. monolopha* is of a pure white or delicate rosy colour, and these colours appear to vary somewhat with the seasons. An extensive account is given of the development of this species. *P. dilopha*, found at Trieste, has externally very much the same appearance as the preceding form, but it is much smoother, and there is a striking difference in the characters of those spicules which belong to the class of hard structures which Oscar Schmidt has distinguished as *candelabra*, for two, and not one only, of the four primary rays are directed towards the limiting surface, and both these divide into a number of secondary rays. Similarly, *P. trilopha* (Naples) has at least three tufts of rays projecting outwards. In *Plakortis* no quadriradiate spicules would appear to be present, and, as in *Plakinastrella*, the "candelabra" are absent. This last-mentioned form has quadri-radiate spicules, and these, as also the tri-radiate forms, take on an anchor-shape in the cortical layer.

Dysideidæ and Phoriospongiæ.*—Dr. W. Marshall gives an account of these two groups of sponges, which appear to have no specially close relation to one another, although they are both remarkable for the fact that they take up foreign bodies to aid in the formation of their skeletons. Almost all the material which the author studied came from Australia, and was handed over to him by Professor Haeckel, who has himself worked a good deal at these forms.

After an introduction, in which the history of the knowledge of these sponges is reviewed, the following definition of the Dysideidæ is given: they are horny sponges, in which the capacity of adding to their skeleton by the accumulation of foreign bodies is carried to an extreme. It is very rare for even short pieces of fibre to be found devoid of such bodies; almost all the species are provided with a dermal membrane, which is more or less filled by foreign bodies, and not a few have them also throughout the rest of their syncytium, so that the whole body comes to form a compact mass of sand, traversed by a few spaces of the body-cavity.

The genus *Psammascus* is tubular and monozoic; it has the closest resemblance of all the Dysideidæ to the genus *Spongelia*, from which, however, it may be distinguished by the presence of the foreign bodies in its soft parts. The author finds in *P. decipiens* the following constituents in the foreign matter:—

	Per cent.
Pieces of Lamellibranch shells	49
Sand	29
Foraminifera	11
Sponge-spicules	9
Parts of Echinoderms, Sclerodermis, of Gorgonids, Ascidians, &c.	2
	100

Similar tables are given in the course of the descriptions of the species of the genus *Dysidea: D. favosa, D, callosa*, and *D. argentea.* The sponges of this genus are massive and polyzoic, and there are no foreign bodies in the syncytium.

The genera *Psammoclema* (*P. ramosum*), and *Psammopemma* (*P. densum*) also belong to this family.

In the course of the descriptions, especial attention is directed to the gastrovascular system, and to the arrangement of the fibres. It seems to be certain that the skeleton of all sponges in which the current of water passes in a regular direction, has at any rate its primary fibres arranged in accordance with this direction; and this law would appear to be true whether the skeleton consists of horny fibres only, or of hard structures only, or of both combined.

An interesting observation made on an oviform *Stellospongia*, in

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* Zeitschr. wiss. Zool., xxxv. (1880) pp. 88–129 (3 pls. and 1 fig.).

which the almost obliterated gastric cavity was confined to the upper portion, confirms this view; in the lower part the fibres formed an irregular network, while in the upper part the primary fibres were quite regularly disposed in relation to the longitudinal axis of the sponge.

The Dysideidæ (with the possible exception of *Psammascus*) appear to form a very well defined family, allied to the Spongeliadæ, of which group *Psammascus* is perhaps an aberrant form.

The genus *Phoriospongia* contains siliceous sponges, in which, again, we find aggregations of sand; two species, *P. solida* and *P. reticulum*, are described. They both come from Tasmania, and appear to be allied to the Cionidæ or to *Vioa;* from the latter, however, they differ by the possession of bihamate spicules.

The author's account is not so complete as he would wish to make it, in consequence of the state of preservation of the soft parts of the sponges; that these may be well seen, it is necessary to plunge the living sponge into strong alcohol.

Protozoa.

Bütschli's 'Protozoa.'*—Parts II.–VI. of this work, with plates v.–vii., have been issued together, so that p. 160 is now reached, but the subject of the *Rhizopoda* is not yet completed. This is partly to be explained by the fact that the Monera and other non-nucleated (cytod) forms are included under this head. As may be imagined, the works of Carpenter and Williamson are largely drawn on for the plates illustrating the Foraminifera, but the sources are always acknowledged. An original sketch is given of a curious variety of *Orbitolites*, from the Samoa Islands, and two others of the remarkable *Polytrema*, in one of which the arrangement of the superjacent lamellæ is very well shown. Some of the figures are from more or less rare journals.

Classification of the Gregarinidæ.† — Dr. B. Gabriel has a preliminary communication on this subject, on which nothing definite has been done since Stein established his three families—Monocystideæ, Gregarinæ, and Didymophyidæ.

Gabriel proposes to form three divisions and to name and characterize them thus:—

I. *Greg. Isoplasta.* The Gregarine-germs and the Myxomycetes-series arise at the same time; both arise from the differentiated body-mass, Cystoplasta. Myxomycetes-forms represented by plasmodia, pigments.

II. *G. Proteroplasta.* The body-mass of the generating Gregarine is differentiated into a Myxomycetes-plasmodium; from this arise the Gregarine-germs, Acystoplasta. These contain the forms that are phylogenetically the oldest. Plasmodium simple.

III. *G. Hysteroplasta.* The Gregarine-germ arises first; the myx-series arise from definite modifications of the Gregarine-germ

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* See this Journal, iii. (1880) p. 662.

† Zool. Anzeig., iii. (1880) pp. 569–72.

(amœboid bodies), and from these alone, Cystoplasta. The plasmodia exhibit radiating prolongations, pigments, calcareous corpuscles, &c. This division contains the forms that are phylogenetically the youngest.

It will be seen that Dr. Gabriel finds the best key to the arrangement of this group by a reference to the mode of development of the young. At any rate, whether it be accepted or no, it seems pretty clear that the progress of investigation has clearly shown that it is impossible to be content with Stein's classification; for

(1) The presence or absence of a septum is not associated with any important morphological or reproductive characteristics.

(2) There is a form intermediate between the Gregarinidæ (sen. strict.) and the Monocystidæ; and that form is a true *Monocystis* in youth, but develops a number of septa when mature.

(3) Many of the Monocystidea have a more complicated developmental-history than many of the Gregarinidæ proper.

The author here again repeats the statement that reproduction in the Gregarinidæ is not always preceded by an encysted condition.

Radiolaria in the Italian Jasper.[*]—Professor Dante Pantanelli publishes a description and plates of the Radiolaria, which he a few months ago announced[†] having found in the Italian Jasper (diaspro), of Tuscany, &c. He describes 32 species, of which 7 occur in the lias, 1 in the chalk, and all of the 32 in the eocene; among which the Peripylæa and Monopylæa are well represented, while the Actometræ furnish only one species of *Dorataspis*. The family of Discidæ, with several *Euchitoniæ*, is most abundant.

This brings up the total number of known Radiolaria to 895, of which 492 are fossil.

The deposit of jasper is considered to have taken place at a depth of not less than 1000 metres.

Cycloclypeus and Orbitoides.[‡]—Dr. K. Martin wishes to extend the knowledge of the results of his investigations into the Foraminifera from the tertiary strata of Java. After an account of the characters of the first genus, he expresses the opinion that it is almost impossible to make "good species" in it without the aid of microscopical examination; the chambers vary greatly in size in different individuals. On the other hand, the embryonal chambers always appear to have a specific value. To take an example from the new species (*C. communis*) which the author here forms, we find him commencing with a description of the lens-shaped shell of the young; and so again for the next (*C. neglectus*), in which attention is drawn to the centre of the shell. *C. annulatus* would appear to be especially distinguished by its sculpturing. In the genus *Orbitoides* he forms the new species *O. Carteri*, *O. gigantea*, and *O. radiata*, and he takes occasion to point out that he thinks that Carpenter and his followers have gone too far in enlarging

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[*] Mem. R. Accad. Lincei, viii., June 6th, 1880.

[†] See this Journal, iii. (1880) p. 819.

[‡] Niederl. Arch. Zool., v. (1880) pp. 185–206 (2 pls.).

the boundaries of species, that we are thereby apt to lose some connecting links, and that, at any rate, we can always unite species.

Reproduction of Euglypha alveolata.[*]—Dr. A. Gruber makes the remarkable observation that the shell-covering of the young of this Protozoon is formed by the mother. When one of these creatures is about to reproduce itself, protoplasm is to be seen passing out from the orifice of the shell, which is shortly followed by the highly refractive, disk-like bodies which lie beside the nucleus of the parent; these cover the protoplasm already extruded. Sometimes the young is matured within the space of an hour, and is then found with its orifice lying close to its parent. A strange phenomenon still remains; the young has still to obtain its nucleus, and that it does direct from the mother, whose nucleus is at this period much larger than ordinarily. Gradually beginning to extend, the nucleus finally equals the whole cell in length; it then becomes constricted; the posterior portion is withdrawn into the mother, while the anterior part passes into the daughter-cell. Then there occurs in both cells an active streaming movement, during which the nucleus is much less apparent; after half an hour this streaming ceases, and the two nuclei are apparent, and have taken up their typical position. This division of the nucleus after that of the protoplasm is, as Professor Gruber remarks, worthy of especial attention.

BOTANY.

A. GENERAL, including Embryology and Histology of the Phanerogamia.

Fertilization of Cobæa scandens.[†]—W. Behrens describes the mechanism of fertilization in *C. scandens*, commonly cultivated in greenhouses in this country, which is effected by humble-bees, especially *Bombus muscorum*, and draws a very interesting comparison with the mode of fertilization in *Cobœa penduliflora* of Carácas, as described by A. Ernst.[‡] Both species are apparently absolutely dependent on cross-fertilization, all attempts at self-fertilization having failed.

Multinucleated Cells in the Suspensor of some Leguminosæ.[§]—In pursuance of the recent observations of Schmitz, Treub, and others[||] as to the occurrence of several nuclei in the cells of certain Algæ, and in those of the laticiferous vessels and liber-fibres, and in unison with those of Hegelmaier to the same effect in the suspensor of some dicotyledons,[¶] M. L. Guignard describes the occurrence of several nuclei in the cells of the suspensor of certain Leguminosæ belonging to the tribe Vicieæ.

In *Vicia pisiformis* and other species, *Orobus angustifolius*, *aureus*,

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[*] Zool. Anzeig., iii. (1880) pp. 582–4.
[†] Flora, lxiii. (1880) p. 403.
[‡] See this Journal, iii. (1880) p. 822.
[§] Bull. Soc. Bot. France, xxvii. (1880) pp. 191–3.
[||] See this Journal, ii. (1879) p. 606; iii. (1880) pp. 111, 303, 482, 493.
[¶] Ibid., iii. (1880) p. 979.

variegatus, *niger*, *roseus*, &c., and *Lathyrus heterophyllus*, the suspensor is composed of only four cells, of which the two upper ones are very long and the two lower ones shorter and round or ovoid, supporting the young embryo. They are derived, after fertilization, from a single primitive cell, which divides both transversely and longitudinally, subsequent to the division of its nucleus. In the protoplasm which fills each of these cells, a larger number of nuclei are then formed by the further division of the first four. The disposition of these nuclei is not always regular; they are usually scattered throughout the layer of protoplasm which lines the cell-wall. They are most commonly spherical, but frequently ovoid, and are readily distinguished from the nuclei of the embryo-sac.

Although not necessary, the employment of reagents greatly facilitates their observation. A solution of cochineal, very slightly acidulated with acetic acid, gives them a red tinge which distinguishes them from the pale rosy tint of the protoplasm. They have generally a moderately large nucleolus. The same cell often presents them in various stages of development; they then resemble the nuclei of the embryo-sac, but they never, like these, become clothed with a cellulose-wall.

The author is unable to assign a cause for this multiplicity of nuclei. It is not exclusively the size of the cells; as in some Orchideæ we find cells as large, with only a single nucleus. It is probably connected with some physiological function.

Open Communication between Endosperm-cells.*—An examination of the endosperm of certain seeds—*Areca oleracea*, *Phœnix dactylifera*, *Strychnos nux-vomica* and others—by Dr. E. Tangl, has determined the fact that the thickened walls of the endosperm-cells are penetrated by a system of canals, through which an open communication is established between adjacent cells, causing a continuous connection of their protoplasmic contents. This he believes to be of great advantage to the plant in the germination of the embryo. An analogy is drawn between the structure of this endosperm-tissue and that of sieve-tubes. The endosperm of *Strychnos* is bounded outwardly by a layer of elongated cells, the longer axis of which stands at right angles to the surface of the tissue. Above this layer begins the true endosperm-tissue, the cells of which, the nearer they are situated to the centre, are larger and characterized by a greater capacity of swelling in the cell-wall. It is these cell-walls through which the communication-system appears to exist.

Modification of Palisade-tissue.†—The ordinary palisade-tissue, so commonly met with beneath the epidermis of the upper side of leaves, consists of elongated tubular cells, with their longer axis at right angles to the surface of the leaf, each cell constituting a palisade. Haberlandt has observed in certain leaves a deviation from this structure, in which the palisades are not single cells but branches of cells. The walls of each cell are folded in at right angles to the

* Jahrb. wiss. Bot., xii. (1880) pp. 170–90 (3 pls.).

† Oesterr. Bot. Zeit., xxx. (1880) pp. 305–6.

leaf, so as to divide it more or less completely into several palisade-like cells. This structure was observed in many Ranunculaceæ, as *Anemone, Caltha, Trollius, Pæonia, Aconitum,* and *Clematis;* in *Sambucus;* among Monocotyledones in *Alstrœmeria;* and in some grasses, as *Elymus, Bambusa,* and *Arundinaria;* in *Pinus;* and in the fronds of *Adiantum* and *Dodea.* The function does not appear to differ from that of the ordinary palisade-tissue.

Formation of Healing-tissue and Fall of the Leaf.*—In an exhaustive treatise on the nature of the tissue formed to protect wounds in the process of healing, and on the phenomena connected with the fall of the leaf, Freiherr v. Bretfeld distinguishes the three following different modes of healing, characteristic of different plants:—(1) By the drying up of the surface of the wound; (2) by the formation of periderm; (3) by the formation of reticulately thickened cells.

Membrane of Bordered Pits.†—J. Moeller returns to the controversy respecting the true explanation of the appearances presented by bordered pits. He dissents from von Höhnel's view, that the so-called "capitulum" (*Köpfchen*) is the thickened closing-membrane of the bordered pit, regarding it, on the contrary, as the border itself, that is, the broadened margin of the pit. This and some other points in the anatomy of these structures he illustrates by the action of chemical reagents on the different pits.

Underground Stomata.‡—R. Hohnfeldt has examined the stomata on the underground axial organs and scale-like leaves of a great variety of species belonging to seventy-one different families.

On the axial organs the number of stomata usually increases towards the apex; but exceptions occur in the lower portion of the aerial stem of *Prunella vulgaris,* and the green branches of *Rubus Idæus,* on which there are a greater number than on the upper part; in the latter plant there are fewer on the aerial than on the underground part of the stem. In *Lysimachia vulgaris* the number is small on both the aerial and underground stem.

When the ordinary leaves have stomata, this is also the case with the underground scale-leaves, and the number is generally greater towards the apex than at the base; but they are usually fewer on an equal surface than on the foliage leaves. *Trientalis europæa* furnishes an exception to this rule, where on a superficies of 1 sq. mm. from the upper, and 1 sq. mm. from the under side of the foliage leaves, there were counted 58 stomata; on the same superficies of the scale-leaves, 150.

While the foliage-leaves, with the exception of floating-leaves, have almost always more stomata on the under than on the upper side, the reverse is often the case with the underground scale-leaves.

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* Jahrb. wiss. Bot., xii. (1880) pp. 133–60.

† Bot. Ztg., xxxviii. (1880) pp. 720–29.

‡ Hohnfeldt, R., 'Ueber das Vorkommen u. die Vertheilung der Spaltöffnungen auf unterirdischen Pflanzentheilen,' Königsberg, 1880. See Bot. Centralbl., i. (1880) p. 1161.

This may possibly be the result of a tendency for the development of stomata to take place chiefly on those parts which are most protected from external influences.

With reference to the distribution of the stomata, the author divides plants into three groups, as follows:—(1) The foliage- and scale-leaves have stomata only on the under or outer side respectively. (2) The scale-leaves have them on both sides, the foliage-leaves on the under side only. (3) Both kinds possess stomata on both sides; but the foliage-leaves more on the under, the scale-leaves more on the inner side.

In form the underground stomata are almost always of equal length and breadth. They occur only on those plants whose habitat is sufficiently dry for the tissue to be porous enough for gases to permeate. None were found on the underground organs of *Senecio sarracenicus*, *Campanula glomerata*, *Monotropa Hypopitys*, *Menyanthes trifoliata*, *Lamium album*, *Ballota nigra*, *Asarum europœum*, *Typha latifolia*, *Caltha palustris*, *Iris pallida* and *pseudacorus*, or *Pteris aquilina*. On the underground axes the number rarely exceeded 10 per sq. mm.; while on underground leaves it was occasionally much greater: in *Saponaria officinalis*, 272; in *Centaurea Jacea*, 108; in *Trientalis europæa*, 150 per sq. mm.

Sieve-tubes of Dicotyledonous Plants.*—The following results were obtained by K. Wilhelm mainly from the examination of the sieve-tube structures in *Vitis vinifera*, *Cucurbita Pepo*, and *Lagenaria vulgaris*, which may be taken as representatives of two different types, the first belonging to a more complicated, the two others to a simpler type.

Those young bast-cells which are destined to the formation of a sieve-tube undergo as a rule a longitudinal division into unequal cells; the largest of these becomes an element in the sieve-tube; the one or more remaining ones, which are much smaller, but themselves of nearly equal size, form the "companion cells" of the sieve-tube, which may undergo still further division. These companion cells are always much smaller than the cambiform cells; they are marked by containing abundant granular protoplasm with a large nucleus; and the walls which separate them from the sieve-tube always contain a number of pits, which is not the case with those that separate the sieve-tubes from the cambiform cells.

The callous nature of the sieve-plates is not, as previously supposed, the result of a secondary change; on the contrary, the transformation of a pit into a sieve-plate begins with the local change of cellulose into callus. The sieve-pores are formed where the pits in the callus are separated by a reticulation of unchanged cellulose. The callus is, however, not limited to the neighbourhood of the sieve-pores, but may spread itself over the whole plate; and this callus-skeleton, which may be isolated, forms an essential part of every completely

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* Wilhelm, K., 'Beiträge zur Kenntniss des Siebröhrenapparatus dicotyler Pflanzen,' Leipzig, 1880. See Bot. Centralbl., i. (1880) p. 908; also 'Nature,' xxii. (1880) p. 602.

differentiated sieve-plate. The volume of this callus-skeleton varies at different times, increasing with age and with the commencement of a period of rest. Under both these conditions the sieve-pores may become completely stopped; opening again when the period of active vitality recurs. This description applies both to the sieve-plates on the transverse, and to those on the longitudinal walls of the sieve-tubes.

The chemical behaviour of the callus does not agree with that of any known group of substances. With acids and alkalies it swells quickly, and is quickly dissolved if they are concentrated; it is only slightly attacked, or not at all, by ammoniacal oxide of copper. It is not coloured by an alcoholic solution of iodine; while potassium iodide colours it yellow or brownish yellow; with the addition of Schultz's solution an intense red-brown colour is produced; this substance alone causes no change of colour, but a considerable swelling. In the polarizing apparatus it remains dark.

While the sieve-tube is in process of formation, a characteristic change takes place in its contents, in the formation of isolated drops or irregular masses of a colourless or yellowish shining mucilage apparently rich in nitrogen; these appear in the layer of protoplasm which lines the cavity of the young bast-cells; and their appearance is followed by the disappearance of the nucleus. These separate masses unite, as a rule, into a parietal band, which is usually many times narrower than the cell. This always remains distinct from the granular protoplasmic parietal layer of the cell itself; while the fluid contents is known as the " sieve-tube-sap."

The author was unable to observe more exactly the origin of the sieve-pores and the commencement of the open communication between the separate cells. It probably takes place by the outgrowth of protuberances from the protoplasmic parietal envelope of the sieve-tube, which enter the sieve-pores from opposite sides where two sieve-plates lie opposite to one another, and unite to form connected strings.

The probable presence was determined, in *Lagenaria* and *Cucurbita*, but not in *Vitis*, of an interior tube, within the parietal protoplasmic layer stretched out between the sieve-plates, and also penetrating the sieve-pores, formed apparently from the substance of the mucilage. The actual perforation of the sieve-pores, doubtful in some cases, was proved in others by the connection between these protoplasmic envelopes of adjacent sieve-tubes.

The presence of starch-grains in the sieve-tubes was established by the author in the case of *Vitis*. They are of considerable size, 1·5–2·5 mm. in diameter, and are present when the tubes are still closed, chiefly in the neighbourhood of the septa. Their size precludes the hypothesis that they pass through the sieve-pores.

In the vine, sieve-tubes occur in the medullary rays, by means of which a communication is kept up between the elements of adjacent bast-rays. They result from the transformation into sieve-tubes of a continuous row of cells of the medullary ray, which penetrate it usually in an oblique direction. Neither these nor the starch-grains were observed in *Lagenaria* or *Cucurbita*.

The author was not able satisfactorily to determine the function of the sieve-tubes; but inclines to the view that they serve for the transport of insoluble substances from one part of the plant to another.

Cork-growths on Leaves.[*]—E. Bachmann has studied the nature of the cork-growths which appear on the leaves of many trees and shrubs, including *Ilex*, *Zamia*, *Cryptomeria*, *Ruscus*, *Eucalyptus*, *Peperomia*, *Anthurium*, and others, most commonly on the under side. The layer in which the formation of cork commences is, in the majority of cases, the first hypodermal layer, less often the epidermal, less often still a lower layer; from this layer it usually extends to others also. The mature development of the tissue may be referred to two types. In some cases the entire structure has the form of a wart-like elevation projecting above the surface of the leaf; all the walls are then parallel to one another, and to the surface, and the cells are arranged in very regular radial rows; the whole tissue is formed by the growth and divisions of a single layer. The second variety of cork-structure occurs less often on the surface than in the interior of the leaf. While originating from a single layer, the cork-formation advances towards the interior; the cork-walls are here also tangential, but usually oblique to the surface of the leaf. Where the parenchyma of the leaf contains large intercellular spaces, these become filled with the cork-structure. In contrast to the cork-formation of the stem, that of the leaf is by no means constant for the same genus or even species; even on the same leaf the structures of this nature may vary in their origin and in their course of development.

Heliotropism.[†]—In pursuance of his previous investigations of this subject,[‡] Wiesner now publishes an elaborate paper, in which the following are some of the more important results arrived at.

In contrast to the ductility, the elasticity of the cell-wall decreases from the lighted to the shaded side; in organs with heliotropic curvature, the tissue-tension occurs only between the epidermis and parenchyma; later also in the latter. The heliotropic sensitiveness of an organ is measured by the rapidity with which the turgidity of the cells on the shaded side increases in contrast to that on the light side. It is also greater the more ductile the cells remain on the shaded side, and the less elastic the illuminated cells become. In opposition to the usual theory, the author shows that in many cases, especially in plants that are very sensitive to heliotropism, the most favourable conditions do not occur in the maximum zone of longitudinal growth; strong turgidity on all sides being a hindrance to heliotropic curvature. The usual supposition that organs are especially heliotropic when etiolated, is incorrect. Etiolated organs which are capable of growth and susceptible to heliotropism, become still more susceptible when slightly illuminated on all sides, depending on the decrease of turgidity. Negative heliotropism must also be regarded as a phenomenon of growth.

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[*] Jahrb. wiss. Bot., xii. (1880) pp. 191-235.

[†] Denkschr. K. Akad. Wiss. Wien, xl. (1880).

[‡] See this Journal, ii. (1879) p. 593; iii. (1880) p. 984.

In reference to the relation between intensity of light, growth, and heliotropism, the following are Wiesner's conclusions:—(1) As the intensity of light decreases, the growth of the internodes gradually accelerates, if strong heliotropism has been induced by the maximum light-intensity. (2) If the maximum intensity of light is too great to induce obvious heliotropism, the increments rise, with the decreasing illumination, to a certain limit; a continuous increase of the length of the internodes then again taking place.

In opposition to the popular view, negatively heliotropic roots grow more and not less rapidly in the dark; this conclusion being confirmed by F. Darwin, and very simply by the concurrence of positively and negatively heliotropic elements in the same organ.

The paper concludes with the record of a great variety of observations on different organs.

Influence of Light on Germination and Respiration.* — M. Pauchon states, as the result of a series of observations, that light always promotes the absorption of oxygen by germinating seeds, the quantity of oxygen absorbed in the light being from $\frac{1}{4}$ to $\frac{1}{3}$ greater than in the dark, and exhibiting a gradual proportional variation. A secondary action of light was observed, lasting for several hours, a portion of the daylight being absorbed by the seed, and consumed during the night. The difference in the amount of oxygen absorbed in the light and in the dark is greater in winter than in summer, showing that light acts more energetically at a low than at a high temperature.

These facts seem to explain the transformation of legumin into asparagin. Asparagin, the form in which the reserve albuminoid substances are transported in the germination of the Leguminosæ, only disappears when the plant is exposed to the light, and remains in those cells which continue dark. Asparagin contains less carbon and hydrogen and more oxygen than legumin and the other proteids; and its transformation into legumin is thus effected in light which accelerates the absorption of oxygen.

Effect of the Intensity of Light on the Decomposition of Carbonic Acid by Plants.† —M. Famintzin has carried out a number of experiments for the purpose of deciding the question whether there is an optimum of light-intensity, an increase above which is unfavourable to the decomposition of carbonic acid. These experiments were divided into two sets.

1. Experiments in sunshine in a mixture of air and CO_2, and then in water containing CO_2.—The sunshine was in some cases allowed to fall direct on the object, in others it was moderated by one or more thicknesses of paper. The result was that in a large number of plants an optimum of light-intensity was established for the decomposition of CO_2. Above this there was no increase in the quantity

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* Comptes Rendus, xci. (1880) pp. 692–4 and 864–6; and Ann. Sci. Nat. (Bot.), x. (1880) pp. 81–192.

† Bull. Acad. Imp. Sci. St. Petersburg, xxvi. (1880) pp. 296–314; and Ann. Sci. Nat. (Bot.), x. (1880) pp. 67–80.

decomposed, while in some cases there was even a decrease in the evolution of oxygen. The author does not, however, conclude from this that the same is necessarily the case for all plants. It is not only possible, but even probable, that with certain plants the light which reaches the chlorophyll-containing tissue, through the strongly developed epidermis or other structures, is so weakened that the optimum is not attained even in the brightest sunshine.

2. Experiments with a gas-flame of an illuminating power of about 50 candles, partly in air and partly in water containing CO_2.—A very considerable decomposition is effected by this flame, on the average about one-third of the amount effected by direct sunlight; a result quite in accordance with the existence of an optimum. The existence of such an optimum of light-intensity for the evolution of oxygen, is in all probability intimately associated with the well-known changes of form and position of the chlorophyll-grains in direct sunshine, by which they turn their narrow edge towards the light, and thus diminish the amount of incident light. The establishment of this optimum is of great importance in exact experiments on the influence of the various rays of light on the decomposition of CO_2, and offers some explanation of the results, which at present appear contradictory.

Decomposition of Carbonic Acid by Plants in Artificial Light.[*]—In the year 1865, M. A. Famintzin experimented on the action of the light of a creosine lamp on *Spirogyra*, and showed that if filaments of the alga, from which the starch had disappeared from long immersion in darkness, were exposed to the action of this light, grains of starch again shortly made their appearance in the chlorophyll-bands. The starch thus formed was assumed to be the product of the assimilation of carbonic acid, although the evolution of oxygen was not experimentally proved. In order to settle the doubt raised by Böhm, Famintzin has now repeated the experiment with *Spirogyra* and other plants, and proved the elimination of oxygen.

Action of Light on the Formation of the Red Pigments in Plants.[†]—Professor Batalin has obtained the following results from experiments on germinating seeds of *Polygonum Fagopyrum*. Pure white light is necessary for the formation of the pigment; if decomposed, it is not sufficient; the intensity of colour depending on the degree of illumination. A small amount of light, less than is necessary for the production of chlorophyll, is sufficient to initiate the formation of the pigment, if with a minimum duration of from four to ten hours. Under these conditions, a secondary coloration also takes place of seedlings grown previously in the dark; but if they are entirely excluded from light, they perish without turning red. A high temperature is favourable to the formation of the pigment. Chromogen is stored up in the axial structures, rhizomes, tubers, bulbs, &c. As the cells increase in age they lose their capacity for producing the pigment.

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[*] Bull. Acad. Imp. Sci. St. Petersburg, xxvi. (1880) pp. 136–42; and Ann. Sci. Nat. (Bot.), x. (1880) pp. 62–6.

[†] Acta horti Petrop., VI., ii. pp. 279–86. See Bot. Centralbl., i. (1880) p. 966.

Influence of Annual Temperature on Change of Colour in Leaves.*—According to H. Hofmann, if a thermometer be freely exposed to sunlight, and the readings above 0° C. added together from the 1st of January to the day in autumn when the turn of the leaf is general, and the same practice pursued for several years, a curve can be constructed which will show considerable variations. If then another curve is constructed below it, composed of the various days on which the change of colour became general, there will be found a correspondence which cannot be accidental, but which, on the contrary, has been confirmed by so many observations, that the author does not hesitate to formulate it as the expression of a law. The temperatures of January and February, the time of rest for plants, cannot exercise any influence, neither is it probable that of April or May does so, when the leaves first appear, and as there is no regular interval of time between the budding of the leaves and their turn, the few weeks immediately previous to that period are the most important. The more cloudy the autumn, and the lower the sum of the temperature of the last month of it, the longer the leaves remain green. The author draws attention to similar results to be observed with plants grown in shade, although their behaviour under such conditions is not so regular.

Variation with Altitude of the Colouring Matters of Flowers.†—The modifications produced in the colour of flowers with varying altitude has been made a subject of observation by M. G. Bonnier during a recent tour in Austria and Hungary. To compare the colours he had recourse to a chromometer, by which variations may be detected which it is impossible to observe by simple inspection. The variations, indeed, are generally less intense, in the present case, than those corresponding to different latitudes which are very striking. In a large number of species, a comparison of the tints at two, three, four, and sometimes five different altitudes, showed, beyond doubt, an increase of colour with altitude. This was very pronounced in *Myosotis sylvatica*, *Campanula rotundifolia*, *Ranunculus sylvaticus*, and *Galium cruciatum;* and, on the contrary, weak in *Thymus serpyllum* and *Geranium sylvaticum*. In ascending, the rose-colour is frequently found to appear in the usually white or slightly coloured flowers of *Bellidiastrum Michelii*, *Bellis perennis*, &c. Microscopical examination on the spot, in many cases, proved that the increase of tint is not due to change in distribution of the colouring matters, but that it is the increase of the number of pigment-grains for a given surface, or a more pronounced tint of the coloured liquid in the cells, that gives the more intense colour. The phenomena are connected by the author with the increase of solar radiation with altitude, the atmosphere becoming less dense, and the quantity of aqueous vapour being less.

Breathing of Plants and Animals.‡—Mr. J. Jamieson, in a memoir submitted to the Royal Society of Victoria, traces certain resem-

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* Journ. Chem. Soc. (Abstr.), xxxviii. (1880) pp. 910–11.

† Bull. Soc. Bot. France, xxvii. (1880) pp. 103–5. 'La Nature,' 1880. See Engl. Mech., xxxii. (1880) p. 396.

‡ Journ. Chem. Soc. (Abstr.), xxxviii. (1880) p. 911.

blances between the breathing of plants and animals, and says that in the same manner as the inhaled oxygen combines with the hæmoglobulin of the blood of animals, and forms more active combinations of the character of ozone, so does it combine in plants with some fluid, which has not yet been identified, but that the presence of ozone in the ripe fruit can be detected by any of the ordinary tests, such as guaiacum or iodide of starch.

B. CRYPTOGAMIA.

Rabenhorst's 'Cryptogamic Flora.'[*]—The publication of a new edition of this work (first published in 1844), has commenced under the editorship of G. Winter, of Zurich, for the Fungi; G. Limpricht, of Breslau, for the Musci and Hepaticæ; F. Hauck, of Trieste, for the Marine Algæ; P. Richter, of Leipzig, for the Fresh-water Algæ; and A. Grunow, for the Diatomaceæ. The editors of the volumes to be devoted to the Vascular Cryptogams, Characeæ, and Lichens are not yet announced.

Each volume, in addition to the special systematic part, will contain a general one, to be devoted to the structure, life, and development of the forms with which it deals, and directions for collecting, preparing, and investigating, so that the work will be available for the beginner as well as for the specialist. With the exception of the Marine Algæ, each genus will be figured.

Cryptogamia Vascularia.

Prothallium of Lycopodium.[†]—In addition to the very defective knowledge which we as yet possess respecting the germination of the spores of *Lycopodium*, and the structure of the prothallium and sexual organs, Dr. G. Beck contributes the following:—

The germination of the spores is attended with the greatest difficulty. The sowing of several species in water was entirely without result. Spores of *L. alpinum*, *annotinum*, and *Selago* showed no signs of germinating when sown, under various conditions of moisture and temperature, on peat, slimy soil, or sand, or when buried in the soil; those of *L. clavatum* manifested some symptoms of germination sown 2 cm. below the surface in ordinary garden soil; but the only success, and that only partial, was with spores of *L. inundatum*, sown on very fine washed peat, and exposed to diffused daylight.

The sphero-cubical spores increase in volume; the cell-wall becomes more transparent, and the solid contents assume a granular character and a slight green colour. The first rupture of the exospore takes place along one of the thickening ridges, but the next between the two other ridges, so that the exospore splits into three lobes. The prothallium now projects obliquely through the lateral opening, and already contains chlorophyll-grains. The first division in the spore takes place after the rupture of the exospore, a septum dividing it into

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[*] 'Rabenhorst's Kryptogamen-Flora Deutschlands, Oesterreichs und der Schweiz. 2 Aufl. Die Pilze; bearbeitet von Dr. G. Winter.' Part 1. (8vo. Leipzig, 1880.)

[†] Oesterr. Bot. Zeit., xxx. (1880) pp. 341–4.

a lower, usually smaller, basal cell, and an upper and larger apical cell. A second wall follows almost immediately in the apical cell, meeting the first usually at an angle of 45°. The succeeding divisions meet the basal wall of the apical cell at the same angle in alternate directions. The division of a segment-cell is always preceded by the accumulation and turbidity of the contents; and after this again becomes clear, an extremely fine membrane is to be made out only with difficulty by the position of the chlorophyll-grains or by intense illumination. Further divisions could be followed out only in a single instance.

The product of the divisions in the prothallium of *L. inundatum* is, therefore, as de Bary has observed, a cellular structure consisting of an axial row of cells bounded at the base by the basal cell, above by the apical cell, and at the two sides by two rows of crescent-shaped cells. The fullest development observed amounted to four cells in the axial row, and in the two rows of crescent-shaped cells, together with the apical and basal cells. The contents consist of a few chlorophyll-grains and an evidently granular nucleus. The length of a 10-celled prothallium was from 0·081–0·099 mm., with a breadth of 0·059–0·062 mm. No indication of reproductive organs was observed.

Germination and Sexual Generation of the Marattiaceæ.*—The development and structure of the prothallium of the Marattiaceæ has at present been only very imperfectly observed. Jonkman has now succeeded in following the germination of the spores, of which there are two kinds. By far the larger number are bilateral, interspersed with a few of a cubico-spherical form. The surface is covered with minute wart-like spines; the wall is transparent and colourless, and is composed of three layers—the endospore, the exospore, itself divisible into two or three layers, and the epispore or perispore, each showing a different colour with different reagents.

The bilateral spores of *Marattia* germinate in seven or eight, the cubical and bilateral spores of *Angiopteris* in five or six days. They at once develop chlorophyll, first in cloudy masses, afterwards in granules. The exospore bursts, and the first cell of the prothallium projects like a papilla between the two lobes; this gradually increases, and becomes rounded off into a ball five or ten times the size of the spore. Numerous divisions of the chlorophyll-grains take place in it. After about four weeks, the first cell-division takes place at right angles to the axis of growth; the first rhizoid, which, like the succeeding one, is never brown, having made its appearance just before. In the next stage of division the quadrant-walls are formed, followed by the octant-walls, so that the normal prothallium soon becomes a mass of cells, distinguished from the prothallia of typical ferns by its deep green colour and moderately thick cuticle. The further development of the prothallium usually proceeds from the four upper octant-cells. One of the quadrant-cells usually becomes the apical

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* Arch. Neerland. Sci. exact. et natur., xv. (1880). See Bot. Centralbl., i. (1880) p. 900.

cell, the rejuvenescence of which continues until the prothallium has assumed its ultimate cordate form.

In *Marattia* the antheridia appear in five, in *Angiopteris* in four months, on both the upper and under surfaces of the prothallium, but neither on the margin nor (as Luerssen maintains) on the lateral lobes. They are formed within the tissue of the prothallium, and never project above its surface. Their structure is quite different from that in the typical ferns, and even from that in Osmundaceæ. From a single prothallium-cell there are produced, by successive divisions, a central cell, two outer cells, and a three-cornered stigmatic cell, which is thrown off when the antheridium is mature. Within the central cell are formed from twenty to two hundred antherozoid mother-cells.

About ten months after the spores are sown, both in *Marattia* and *Angiopteris*, the archegonia make their appearance on the under, and sometimes also on the upper surface of vigorous prothallia, but exclusively on the median cushion-like thickening. They resemble those of *Ophioglossum* or *Salvinia* more closely than those of typical ferns, projecting above the prothallium only by the two uppermost rows of cells of the neck. Their development takes place as follows:—A superficial cell of the prothallium, the mother-cell of the archegonium, divides into two daughter-cells by a wall parallel to the surface, the upper one being the mother-cell of the neck, and the lower and larger one the central cell. From the former are formed, by two successive divisions at right angles to one another and to the surface, four cells, each of which becomes the mother-cell of a row of neck-cells. The central cell divides by a bulging wall into a lower cell, termed by Jonkman the ventral cell, and an upper neck-canal-cell. The ventral cell divides subsequently into two daughter-cells, the upper of which becomes the ventral canal-cell, and the lower one the oosphere. Both of these, as well as the lower rows of neck-cells, become gradually surrounded by a number of small cells capable of swelling—the mantle-cells. The antherozoids were seen by the author forcing their way into the open neck of the archegonium, and some of them disappearing in the neck-canal; but their history was not traced any further.

This knowledge of the sexual generation of the Marattiaceæ appears to widen their separation from the typical ferns; but their true systematic position cannot yet be determined with certainty.

Muscineæ.

Structure of Orthotrichum.[*]—Venturi has made an exhaustive examination of this difficult genus of mosses, especially with reference to the simplicity or duplicity of the peristome, the number of teeth in the peristome, the presence of appendages to the cilia of the inner peristome, the nature of the cells of the leaf, &c. In classifying the species he also lays great stress on the variation in the nature of the stomata in the capsule, whether lying in the same plane as the epidermis (*phaneroporous*), or depressed beneath it (*cryptoporous*), and on the correlated position of the peristome-teeth in the dry state, whether erect and spreading radially, or recurved towards the outer surface of

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[*] Rev. Bryol., vii. (1880) pp. 65–76.

the capsule, and applied to it either along their whole surface or at the apex only. According to these characters, he divides the species into six natural groups, as follows:—

I. *Orthotricha cupulata.*—Cryptoporous; peristome-teeth dry, erect or spreading radially, with indistinct curved lines and no or very few papillæ:—*O. cupulatum, anomalum, urnigerum, Schubartianum,* and *Venturii.*

II. *Orthotricha rupestria.*—Phaneroporous; peristome-teeth erect, with a larger or smaller number of scattered thick papillæ, without the characteristic curved lines of the previous group:—*O. rupestre, lævigatum, Sturmii, Blyttii, ætnense, flaccum, Shawii, Franzonianum, ovatum,* and *Holmgreni.*

III. *Orthotricha straminea* (?). — Cryptoporous; peristome-teeth recurved and finely punctated. This includes three subdivisions.

1. Neck of the capsule suddenly constricted to the seta:—*O. fallax, Philiberti,* and many exotic species.

2. Peristome with eight teeth so strongly recurved that they are applied to the outer wall of the capsule through their whole length:—*O. rivulare, Sprucei, stramineum, alpestre, pallens, patens, Rogeri, Braunii, tenellum, microcarpum, pumilum,* and *polare.*

3. Peristome-teeth split in the middle when dry, and after the operculum is thrown off, and recurved so that their apices touch the wall of the capsule:—*O. pulchellum* and *Winteri.*

4. Seta elongated, so that the capsule is elevated above the perichætial leaves, as in *Ulota*:—*O. leucomitrium* and many exotic species.

O. diaphanum and several scarcely distinguishable exotic species appear to occupy a special position in this group, having coloured or setose apices to the leaves and peristome-teeth, of which there are sixteen outer and sixteen inner, streaked by fine vertical lines.

IV. (unnamed).—Phaneroporous; peristome-teeth more or less densely covered with papillæ, recurved when dry:—*O. Shawii, leiocarpum, Lyellii, speciosum, affine, fastigiatum, apiculatum, neglectum, elegans,* and *medium.* This group is also divided into three subdivisions.

1. Outer peristome composed, when ripe, of sixteen teeth, which are recurved after the operculum is thrown off, so that their apices only touch the wall of the capsule, but are so densely covered with papillæ that the septa are scarcely perceptible:—*O. Shawii, leiocarpum, Lyellii.*

2. Capsule narrow, slightly striated, raised above the perichætium on a long seta; white peristome-teeth recurved, so as to form almost a projecting ring round the mouth of the capsule:—*O. speciosum; O. elegans* presents a transition to the next section.

3. Peristome-teeth not split, and therefore always a multiple of eight; papillæ more numerous than in group II. 2, smaller than in group I.; hence, in consequence of the opacity of the teeth, curved lines are to be seen in all directions among the papillæ of an entirely different character from those in group I.; curved lines of the same kind are also sometimes visible on the cilia of the inner peristome; the cilia are also sometimes provided with appendages similar to those of *O. speciosum*:—*O. affine, fastigiatum, neglectum, apiculatum,* and *medium.*

V. *Orthotricha arctica.*—Phaneroporous; peristome-teeth finely punctated, recurved not quite to the wall of the capsule; seta elongated, raising the capsule above the perichætium. This group forms a kind of connecting link between the *rupestria*, *straminea*, and *affinia*, and its species are also characterized by their invariable habit, and their exclusively Arctic habitat:—*O. arcticum*, *microblepharum*, *Sommerfeltii*, and *brevinerve*.

VI. *Orthotricha obtusifolia.*—Papillæ of the peristome-teeth different from those in the other groups; leaves with recurved margin. This group ought possibly to constitute a distinct genus.

Structure of Orthodontium.*—The rare moss *Orthodontium gracile*, hitherto known only in a few localities in England, has been recently found also in France; and, from a comparison of specimens from all the stations, M. Boulay considers the customary description of the peristome to be inaccurate, and proposes to substitute the following:—Processus peristomii interni dentibus externis æquilongi, humiditate conniventibus, apice contiguis.

Sphagnum Austini, Sulliv.†—According to C. Warnstoff this rare turf-moss is not distinguishable from *S. cymbifolium*, except as a varietal form united with the typical form through *S. papillosum* Lindb. The character derived from the number of branches in a tuft is not always constant in the same species. The only constant characters to be relied on appear to be the cortical layer composed of four layers of cells, and the densely crowded comb-like projections on the inner walls of the hyaline cells of the leaves.

Characeæ.

New Fossil Chara.‡—Under the name *Chara Gebhardi*, J. Ottmer describes the spore-fruits (nucules) of a hitherto undescribed species from the upper Kimmeridge clay of the Langenberg, near Oker.

Fungi.

Double Fructification of Polyporus applanatus.§—Since S. Schulzer made the first discovery of the conidial fructification of a *Polyporus*,‖ he has observed the same structure in *P. applanatus*. The lower tuberous part had no trace of any tubular structure at the margin, while the greater part of the upper surface of the pileus appeared as if covered with a red dust. Of the hyphæ which constitute the substance of the pileus, some bend downwards to form the tubular hymenium, others bend upwards to form the cortex of the pileus. This cortex, which is scarcely 1 mm. thick, consists of two layers. The outermost and much the thinnest of these layers is

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* Rev. Bryol., vii. (1880) pp. 84–5.

† Bot. Centralbl., i. (1880) p. 1244.

‡ JB. Ver. naturw. Braunschweig, 1879–80, p. 71. See Bot. Centralbl., i. (1880) p. 1233.

§ Oesterr. Bot. Zeit., xxx. (1880) pp. 321–2.

‖ See this Journal, ii. (1879) p. 314.

composed of roundish cells, which can only with difficulty be separated from one another. From these springs the layer of conidia which covers the upper surface of the pileus. The conidia are of an ovoid form, reddish brown, about 7 μ long and 4 μ broad. When ripe they fall off spontaneously and form a dense umber-purple-brown layer of spores 9 μ long and 5 μ broad, filled with finely granular protoplasm. In the tubes is no true hymenium, but the colourless unthickened ends of the hyphæ project without any definite arrangement into the tubes, and produce at their apices the spores, which resemble the conidia in every respect.

Alternation of Generations in some Uredineæ.*—The following is an epitome of the most recent experiments of M. Cornu on the cultivation of the spores of various Uredineæ :—

Æcidium pini, gathered on the 16th May, was sown during the following night on five plants of *Senecio vulgaris*. Two of these perished at once; on June 1st the circular uredo-pustules were seen on the stem of two of the others, and shortly afterwards on the third, and from there advanced to the leaves. A fortnight later a few teleutospores were observed, the teleutoform being identical with *Coleosporium senecionis*. A second sowing on *Senecio vulgaris* produced no result, and the same was the case with *S. sylvaticus*, *coriaceus* and *crassifolius* and *Sonchus oleraceus*. This alternation had been suggested by de Bary in 1874.

Spores of *Æcidium urticæ*, gathered from *Urtica dioica*, were sown upon *Carex hirta*. After nineteen days uredospores appeared on the leaves, and seven days later the teleutospores of *Puccinia caricis*. No result was obtained on *Carex riparia*. This alternation was also indicated by Magnus, in 1873.

Spores of *Æcidium rhamni*, from *Rhamnus catharticus*, were sown on May 18th, on two pots containing seedling oats; on June 11th pustules of *Uredo rubigo-vera* made their appearance. On June 4th the experiment was repeated; on June 20th a great number of uredo-pustules appeared, rapidly increasing. On July 9th teleutospores of *Puccinia coronata* were seen on the lower leaves. This alternation was also suggested by de Bary in 1864.

The uredospores of *Melampsorella*, from *Moehringia trinervia*, sown on *Alsine media*, germinated after about nine days.

The teleutospores of *Puccinia dianthi*, also from *Moehringia trinervia*, sown on April 28th on *Alsine media* and *Stellaria holostea*, germinated on May 17th, without the intervention of uredoform; as Cornu had previously observed in the case of *P. malvacearum*; a process which he considers probable in all puccinias which germinate directly.

Æcidium columnare.†—This parasite of the silver-fir, which makes its appearance on the under side of the leaves, in the form of columnar yellow bladders filled with spores, has not yet been

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* Bull. Soc. Bot. France, xxvii. (1880) pp. 179–83; and Comptes Rendus, xci. (1880) pp. 98–9.

† Allgem. Forst.-u. Jagdzeit., 1880. See Bot. Ztg., xxxviii. (1880) p. 618.

identified with any other form. R. Hartig has determined it to be the æcidioform of *Calyptospora Gœppertiana* parasitic upon *Vaccinium Vitis-Idæa* and *Myrtillus*. This last develops its resting spores in the cortical tissue beneath the epidermis of the stem of the host, where they form brown swellings. Young silver-firs and bilberries infected with the *Calyptospora* were planted in the same pot. The winter-spores of this fungus, when kept moist, put out vigorous promycelia on which sporidia are developed on delicate sterigmata. These germinated on the leaves of the silver-fir; the germinating filament soon penetrated the tissue, and the golden yellow cushions of æcidia soon made their appearance. A corresponding infection of the leaves of the bilberry with the spores of the æcidium resulted in the same way in the production of the *Calyptospora*. The development of the spores on the leaves of the silver-fir appears to depend on the occurrence of several days of rainy weather; in some years, therefore, the production of the parasite may be entirely suspended. The *Calyptospora* is however persistent in the tissue of the *Vaccinium*.

Maple-parasite, Cercospora acerina.*—A fungus is occasionally found on the cotyledons of the mountain maple, the mycelium of which penetrates the cells, and protrudes through the epidermis in the form of fertile hyphæ with septated conidia curved at the apex; this passes, by swelling and the division of the cells, the walls of which become black, into a resting mycelium, which often retains its power of germinating for a year. Hartig states that it grows also on the soil and in nutrient solutions. The asci have not yet been detected; it is possible that *Sphæria acerina* Wallr., found upon dry maple leaves, may be the same species.

Parasite of Fir-bark, Nectria cucurbitula.†—The fir-trees of Upper Bavaria have been attacked, during recent years, by a fungus which penetrates the bark, chiefly through injuries caused by hail or the weight of snow, or still more, by a microlepidopter, *Grapholitha pactolana*. Hartig states that the mycelium develops mainly in the sieve-tubes, but also in the cortical tissue, and only in the spring; its development in summer is arrested by the want of water in the substratum. The fertile layer appears principally near the base of the stem, where there is a more abundant supply of moisture, in the summer and autumn, as cushions, at first white, afterwards reddish, which break through the bark, and detach firstly conidia, and subsequently red perithecia, the latter probably the result of impregnation. The ascospores are two-chambered, ripen in the winter, and produce on germination a mycelium, on which conidia are again formed in various ways, sometimes directly, sometimes on special shoots. The development of the mycelium and the formation of the conidia can be followed out in a drop of turpentine. The growth of the parasite destroys the bark and cambium; the tree dying as soon as the mycelium has grown completely round the stem.

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* Unters. förstbot. Inst. München, i. (1880) pp. 58–61. See Bot. Centralbl., i. (1880) p. 972.

† Ibid., pp. 88–108.

Nectria ditissima.*—According to R. Hartig, a large part of the diseases to which forest-trees are subject, are due to the attacks of this parasitic fungus. It attacks *Fagus*, *Quercus*, *Corylus*, *Fraxinus*, *Carpinus*, *Alnus glutinosa*, *Acer campestre* and *Pseudoplatanus*, *Tilia*, *Frangula*, *Padus*, and possibly also the apple. It almost always enters through wounds, especially those caused by hail or by the puncture of an insect, *Agrilus viridis;* but in some cases lenticels appear to give the opportunity. The development of the mycelium takes place especially in the autumn. The portion of the bark attacked assumes a black colour. The mycelium is mostly intercellular, and from the extremities of the excessively fine hyphæ are abstricted minute conidia resembling schizomycetes. These are not, however, known to serve for the propagation of the fungus, but bring about the rapid destruction of the cortical tissue. The medullary rays, wood-parenchyma, and vessels are also attacked by the mycelium, causing a brown colour in the wood to the depth of a few millimetres. In damp weather, especially in September and October, the fertile cushions make their appearance, producing first conidia, and then small red perithecia, the result of an act of impregnation that has not yet been accurately followed.

Larch-parasite, Peziza Willkommi.†—R. Hartig believes that the great destruction of larch-forests, which has taken place during recent years in central and northern Germany and Scotland, is mainly due to the attacks of this fungus. It was first described by Willkomm as a *Corticium*, but is a true *Peziza*, specifically distinct from *P. calicina*, which is also abundant on conifers. That this is the true cause of the disease known in Germany as "Krebs," was proved by the writer by actual infection. Its attacks are promoted by the injury inflicted on the branches by insects, by hail, and by a great weight of snow.

The mycelium lives in the cells or intercellular spaces in the bark, bast, medullary rays, resin-passages, and sieve-tubes; it develops only in the autumn and spring, and spreads most quickly in the direction of length of the stem or branch. When the activity of the cambium commences, a layer of cork is formed between the dead and living cambium and the periphery, which is broken through in the autumn by the fungus; the cause of its growth being arrested in the summer is the want of water in its substratum. Connected with the formation of the cork-layer is the flow of resin out of the resin-passages which have not yet been closed by it. The side of the section opposite to the infected part shows also a considerable hypertrophy.

The fructification of the fungus has the form of small cushions, which first produce conidia capable of germinating; the ascophorous hymenium is formed only when the environment is damp, and hence chiefly near the base of the stem and on the under side of the branches.

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* Unters. förstbot. Inst. München, i. (1880) pp. 145–50. See Bot. Centralbl., i. (1880) p. 1134.

† Ibid., pp. 33–57.

Parasitism of Elaphomyces granulatus.* — This fungus occurs in pine-forests only, where it forms large masses; each individual is surrounded by an envelope about 4 mm. thick, formed from the excessive branching of a single branchlet of the root of the pine. According to Reess, the roots branch abundantly within this envelope in a dichotomous manner, and their somewhat thickened ends are enveloped in a closely adherent whitish sheath, of the pseudo-parenchymatous tissue of the fungus. From this sheath mycelial filaments pass on one side outwards into the soil, on the other side inwards into the cortical tissue of the root, thus establishing its parasitism. The hyphæ are in connection with the cortex of the fructification of the fungus, but are very delicate, so that they are ruptured when the envelope is cut away, the fructification falling out quite smooth.

Parasites on Tobacco.†—A tobacco plantation in the neighbourhood of Parma was observed by Professor Passerini to be subject to a variegation of the leaves, which subsequently assumed the form of dry, white, circular spots. This he found to be caused by two fungi, of which he gives the following diagnoses, but which are probably forms of some unknown spheriaceous fungus.

Phyllosticta Tabaci.—Folia primo pallide variegata et paullatim bullata, deinde areolis exaridis, candidis, irregularibus, subconfluentibus, disseminata. Areolæ sæpe steriles, nonnullæ autem medio sordescentes, ibique perithecia atra, punctiformia, foventia et mox lacerata. Spermatia ovoidea, recta, hyalina, b. 7 mk. longa 3 mk. lata. Ad folia *Nicotianæ Tabaci*; Aug.–Sept.

Ascochyta Nicotianæ.—Perithecia in maculis exaridis irregularibus subaggregata, fusca; spermatia ovoideo-oblonga, medio septata et leniter constricta, hyalina, endoplasmate granuloso. In foliis languidis, primo pallide variegatis *Nicotianæ Tabaci*; Aug.

On the leaves were also noticed two other fungus-parasites, *Epicoccum purpurascens* Ehrh. forma Tabaci, and *Macrosporium commune* Rabh.

Rape-disease: Pleospora Napi.‡—Herr v. Bretfeld has observed the great prevalence of this parasite on the rape in various parts of Germany, producing very serious injury to the crop. It appears especially on the siliquæ, causing them to become spotted and yellow, and to burst prematurely. The author assigns the priority to Fuckel's name, *Pleospora Napi.* It should, however, rather be called *Sporidesmium exitiosum* or *Polydesmus exitiosus;* since, although Fuckel regards the latter as the conidial form of the former, he has not proved their identity. The *Sporidesmium* which produces the disease referred to, occurs abundantly in the summer on the leaves, branches, and siliquæ of the rape and turnip; while the *Pleospora* is found in the spring on the dry stubble of both plants, and is much less

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* SB. phys.-med. Soc. Erlangen, May 10, 1880. See Bot. Centralbl., i. (1880) p. 1094.

† Atti Soc. Critt. Ital., xxiv. (1881) pp. 13–16.

‡ Landwirth, 1880, No. 61. See Bot. Centralbl., i. (1880) p. 886.

common. No genetic connection has been certainly established between the two.

Rosellinia (Rhizoctonia) quercina, a Disease of the Root of the Oak.*—R. Hartig has investigated a disease of young oak-trees, prevalent in north-west Germany, which he finds to be due to the attacks of this fungus. The mycelium consists of strings, at first white, each of which is composed of a number of interwoven hyphæ, making its appearance on the roots, as well as in the surrounding earth and on the surface of the soil. It assumes the three different forms following:—(1) Chambered sclerotia, when the infection takes place at the apex of the root, before the formation of periderm; the cortical cells, the walls of which remain, are entirely filled by the polyhedral hyphal cells; (2) mycelial tubes, which are formed especially where the lateral wall springs, and assume a black colour at the periphery; protrusions from these tubes penetrate into the sound tissue of the root, especially the cambium, while under favourable circumstances, new strings spread at the same time in the soil; in times of drought or cold the plant protects itself by a layer of cork from the further attacks of the fungus; (3) sclerotia, formed out of the strings which run along the surface of the root, single hyphæ of which penetrate the cork-cells, rupture them, and produce a pseudo-parenchymatous sclerotium, which persists through the winter or unfavourable season.

The reproduction of the fungus is effected by means of cylindrical conidia which become abstricted from verticillate branches of the mycelium on the surface of the soil; as also by perithecia, the sexual origin of which is highly probable. From the form of the perithecia and spores it belongs to the genus *Rosellinia* de Not.; before the discovery of the perithecia it was referred to *Rhizoctonia.* The injury effected by this parasite is very considerable.

Olpidiopsis, the Parasite of Saprolegnia.†—The spiny spherical bodies (*Stachelkugeln*) commonly found in connection with the tubular cells of *Saprolegnia* and *Achlya*, have often been described, and their true nature much contested. Nägeli first discovered on the swollen filaments of *Achlya prolifera* elongated cells which penetrate the filaments by means of a short tube, and from which escape extremely small motile bodies. These he considered to be non-sexual organs of reproduction. Cienkowski observed the presence of spiny bodies in company with the smooth ones, and came to the same conclusion respecting their nature. A. Braun regarded them as a parasite on the *Saprolegnia*, describing them under the name *Chytridium Saprolegniæ*, as the representative of a new genus. The smooth cells he described as sporangia, and their motile contents as swarm-spores. Pringsheim, on the other hand, to explain what would otherwise be a parthenogenetic development of oospores (oosperms) in *Saprolegnia*, regarded the smooth bodies as male organs, the motile contents as antherozoids; but he offered no explanation of the spined bodies. Cornu, again, gave a decided judgment in favour of the parasitic

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* Untors. förstbot. Inst. München, 1880, p. 1.

† Bot. Ztg., xxxviii. (1880) pp. 689–96, 705–11, 721–6 (1 pl.).

nature of these organisms, and established from them a new genus, *Olpidiopsis*, of Chytridiaceæ, and this view was subsequently adopted by Pringsheim.

A. Fischer has now subjected these bodies to a fresh careful examination, and appears to have fully established their parasitic nature, by following their development and causing them to germinate on filaments of *Saprolegnia.*

The swarm-spores from the smooth sporangia vary greatly in size, averaging between 4 and 8 μ, about twice as long as broad, and biciliated, one cilium being attached to the anterior end, the other to the middle of one side; in the interior is a dark body, which is not a nucleus, but rather a drop of oil. The zoospore is enclosed in a delicate membrane of cellulose, which is thrown off when it penetrates the host. With regard to that part of the *Saprolegnia* attacked by the parasite, the author found that the zoospores of *Olpidiopsis* did not attack those of their host while still in a motile condition, but only after they had come to rest, and then without any passage of the contents of one into the other. But to the young filaments of *Saprolegnia* they attached themselves readily, pierced the filaments by means of a small tube, and emptied their contents into it. The contents then rounded themselves off within the filaments of the host to a motionless body, which soon displayed amœboid motions. These increase greatly in size at the expense of the protoplasm of the *Saprolegnia*-filament. Ultimately the movement ceases, the body contracts into a denser spherical mass, and soon becomes evidently clothed with a cellulose-membrane, and the granules which have already been formed in it increase in number. It has thus developed into a sporangium or *Stachelkugel*, containing a number of refractive granules. The membrane of this body, as well as the spines with which it is covered, are composed of cellulose. The *cellule adjacente*, which Cornu always found in connection with these bodies, does not appear to be invariably present, and cannot have, as he supposed, any sexual function. The spines are occasionally wanting.

While still within the filaments of the host, the granules in the sporangium gradually develop into zoospores. Before this takes place it has put out one or more tubes which pierce the cell-wall of the filament, attaining sometimes a very considerable length, and occasionally branching. At length the zoospores escape through this neck with great rapidity, and in very large numbers. They resemble in every respect those produced in the spineless sporangia, except that they are larger. The spiny sporangia sometimes remain for a considerable time in a resting state, in which case vacuoles have previously been formed in them.

In pure water the zoospores from the spiny sporangia either perish or put out a small germinating filament. If *Saprolegnia* is present in the water, they attach themselves to the filament, perforate it by means of the tube, and empty their contents into it in the same way as those from the smooth sporangia. The result is always the production within the host of a smooth and not of a spiny sporangium. Otherwise, the process of germination is the same; but the smooth sporangia do not appear to have any resting state. A kind of alternation of generation appears thus to be established.

With regard to the systematic position of this organism, it is doubtful whether the genus *Olpidiopsis* can be maintained as distinct from *Chytridium*, Cornu's character of the occurrence of a *cellule adjacente* not being constant. *O. Saprolegniæ* appears to be parasitic exclusively on *Saprolegnia ferax*, not being found on *Achlya prolifera* when the two grow intermixed.

Organic "Dusts" of the Atmosphere.*—M. É. Yung, of Geneva, lately read a paper to the Helvetic Society of Sciences on organic dust in the atmosphere. With regard to its influence on public health, he distinguishes two groups of particles, the spores of fungi of the mould group, and germs of micro-bacteria, the latter being the more important. In agreement with Miquel's observations † at Montsouris, he observed a notable increase of germs during the hot months of summer, and a decrease in winter. Opening globes filled with neutralized bouillon, quite sterilized by heat, on mountains, glaciers, the ocean, in volcanic craters, and various other circumstances, he found that in most cases ten to twenty cubic centimetres of air sufficed to introduce germs of organisms capable of growing and living in successive or simultaneous generations, according to species. Two exceptions are noted: one being that of a globe opened at Geneva after an abundant fall of snow; the bouillon remained quite clear, proving that snow for a time clears the air of germs. The other was that of a globe opened in an isolated ward of the Geneva Hospital, where a diphtheric child was being nursed. On the other hand, fresh snow gathered in winter on the mountains round Geneva, confirmed the previous results as to the extreme diffusion of microscopic organisms.

M. Yung was unable to prove a connection between the number of atmospheric germs and the recrudescence in the same place of a particular contagious or epidemic disease.

Green Bacteriaceæ and Colourless Phycochromaceæ.‡—In connection with the well-known existence of certain Oscillatorieæ (*Beggiatoa* and *Leptothrix*) destitute of chlorophyll, and the discovery of Bacteriaceæ containing chlorophyll, Van Tieghem rediscusses the relationship of these two families.

1. *Green Bacteriaceæ.*—In the rain-water which filled the cavity of the pileus of a young *Polyporus*, in the month of September, the author noticed a thin green layer clothing the cavity. This layer was formed entirely of minute rods of a pure green colour, constricted in the middle, dividing frequently and separating after each segmentation, but otherwise immotile. On removing it to ordinary water, there were produced, after a few days, in a large number of these rods, spores of a spherical or slightly oval form, in all respects similar to the well-known spores of *Bacillus* and other Bacteriaceæ. This seemed to

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* Arch. Sci. Phys. et Nat., iv. (1880) pp. 416–8, 573–91 (1 pl.); Engl. Mech., xxxii. (1880) p. 297.

† See this Journal, iii. (1880) p. 837.

‡ Bull. Soc. Bot. France, xxvii. (1880) pp. 174–9.

place beyond doubt the affinity of the new organism, which Van Tieghem calls *Bacterium viride.*

In May and June the author again observed, in water containing aquatic plants mingled with *Spirogyra*, very slender filaments of a green colour verging on yellow, ordinarily immotile, but sometimes endowed with motion, formed of long cells, and bearing a close resemblance to *Bacillus anthracis.* In September he was able to follow the formation and the germination of the spores. These were oval in form, and were abundantly produced in all the cells of filaments placed for some days in darkness. They were completely colourless. On germinating they gave rise to filaments, which were at first colourless but which rapidly became green on exposure to light. This organism, possibly identical with *Hypheothrix* or *Leptothrix tenuissima*, is apparently common, and is called by Van Tieghem *Bacillus virens.* The same or a very similar form was described by Perty under the name *Sporonema gracile*, in which the formation of the spores was described and drawn by him.

2. *Colourless Phycochromaceæ.*—Two genera have been formed of Phycochromaceæ destitute of chlorophyll—one, *Beggiatoa*, with the ordinary motion of an *Oscillatoria;* the other, *Leptothrix*, immotile. A third form has been studied by Van Tieghem, with colourless, extremely slender, immotile filaments, composed of short cells. It is especially characterized by nodosities in the filament, consisting of permanent cells more refrangent than the rest, which germinate after the rest have disappeared. From this circumstance the author regards it as a true Oscillatoria, which should not be separated from this family and united to *Leptothrix* merely for the absence of motility. Notwithstanding the absence of chlorophyll, and the outward resemblance to a *Bacillus*, there is not sufficient reason for separating this organism from the section *Beggiatoa* of Oscillatoria, and Van Tieghem proposes for it the name *Beggiatoa nodosa.*

The same author has observed a *Spirulina* entirely destitute of chlorophyll forming a thin white layer in an abandoned mill-race. It was extremely slender, and its coils so close together as to touch, and to appear to form a hollow tube. It moved actively by torsion on the axis of the tube; and the very long filaments oscillated at the same time laterally. Van Tieghem calls it *Spirulina alba*, and considers it nearly allied to *S. subtilissima.*

3. *Affinity of Bacteriaceæ and Phycochromaceæ.*—It appears, therefore, that (1) normal chlorophyll occurs in types belonging certainly to the family Bacteriaceæ, and not separable generically from *Bacterium* and *Bacillus;* (2) various Oscillatorieæ are altogether wanting in the blue-green colouring matter; and (3) permanent cells have been observed for the first time in a *Beggiatoa.* Van Tieghem does not, from these facts, draw the conclusions that the distinction between the two families must be abandoned, as was proposed by Cohn in 1875. In the occasional loss of their chlorophyll the Oscillatorieæ do not, in fact, approach the Bacteriaceæ; and, in occasionally acquiring chlorophyll, the Bacteriaceæ do not approach the Oscillatorieæ. The two chlorophylls are not equivalent; that of the

Oscillatorieæ is mixed with phycocyanin, while that of the Bacteriaceæ is normal chlorophyll. Furthermore, the mode of formation of the reproductive cells is quite different. In the Oscillatorieæ it is simple vegetative cells which become slightly transformed by a change in the cell-contents, and a slight thickening of the cell-wall, thus producing permanent cells rather than spores. In the Bacteriaceæ, on the contrary, the true spores are special bodies, of endogenous origin, and differing greatly in their form and properties from the ordinary vegetative cells. The facts above detailed seem to the author rather to confirm the distinction between the two families, than to tend to unite them.

Blue Milk.*—The spontaneous production of blue milk is said by F. Neelsen to be confined to a certain district of the German shores of the Baltic. The production of the blue colour is always accompanied by an evolution of carbonic acid, often in great quantities. The colouring matter has nothing to do with any bacteria, but is dissolved in the serum of the milk. It appears to be nearly related to aniline-dye. There is no foundation for the idea that blue milk is poisonous.

Neelsen determined the presence in blue milk of bacteria in the form of rods with rounded ends, having a length of $2 \cdot 5$–$3 \cdot 5\ \mu$, not always straight, but often curved in various ways. In an early stage they move about with great activity, as if by the aid of cilia, which, however, have never been detected. At a later period, as the milk becomes more blue, they divide by abstriction, ending in the production of torula-like chains, which gradually become stationary. The separate cells of these chains are conidia, which germinate in fresh but not in the same milk. These sometimes become aggregated and enveloped in a common mucilaginous envelope, assuming the glœobacterial form. Placed in Cohn's nutrient fluid, they produce true spores by the swelling up of a portion of a rod, which germinate like the conidia. In potassium nitrate leptothrix-like filaments were obtained.

Mitigation of Fowl-Cholera Poison.†—To obtain the poison in its most virulent form, M. Pasteur states, it should be taken from a fowl which has died, not of acute but of chronic disease. On cultivating this in several solutions of fowl-broth by transferring it in succession from one to the other, it is found that it suffers no diminution of its virulence in the passage. However, experiments made by varying the length of the periods of time during which the solutions are left intact after having the parasite added to them, show that the time allowed for its development is an important element in the question. Thus, with intervals of only from one day to two months between any two successive inoculations of the solutions, no modification of their virulence is experienced, though in proportion as the interval is increased, signs of such a modification appear in the slowness with which

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* Cohn's Beitr. Biol. Pflanzen, iii. (1880) pp. 187–246.

† Comptes Rendus, xci. (1880) pp. 673–80.

death occurs, and in the diminished acuteness of the preliminary symptoms.

On the other hand, with longer intervals than two months, these indications become decided, so much so that the percentage of deaths falls from that of 10 in 10 cases, which occurred in the former experiments, to as low as 1 in 10; and sometimes no deaths take place. Thus a completely vaccinal virus may be obtained.

The rules to which the diminution of the virulence of the poison is subject are not mathematically exact; that is, the diminution of intensity does not vary directly as the length of the interval allowed to the growth of the parasite; but it is certain that death of the parasite ensues sooner or later if sufficient time is allowed, and further, that the standard of virulence attained by any solution is maintained by it so long as the periods of growth are kept constant.

No changes in the appearance of the parasite itself have hitherto been found to accompany the changes in its activity.

With regard to the cause of the diminution of virulence, the fact that the parasite requires contact with the air, and fails to develop in a solution if this is denied it, suggests the possibility that this contact with the air or with some chemical principle contained in it is at the bottom of this remarkable change. By removing the oxygen it may be shown that *it* is the agent which effects this change. This is done by sealing up tubes containing infected solutions, with various proportions of air. At first the solutions become cloudy, marking the growth of the organism. In two or three days they become clear, and the growth is deposited on the sides of the glass. The cause of the clearing is the cessation of growth consequent on the exhaustion of the small amount of oxygen belonging to the enclosed air. On opening these tubes at periods of from two to ten months after sealing, the poison is found to retain its power, which is exactly of the degree at which it stood when first sealed up, whereas growths exposed to the air at the same time are now either dead or weakened in force.

It remains to be seen whether this action of the oxygen similarly affects other organized poisons, in order to deduce a principle from the facts. If it is so, the limitation which great epidemics undergo may here find an explanation. It is noteworthy that the above explanation was arrived at in spite of a former impression formed by M. Pasteur that the facts relating to the attenuation of the poison were due to the existence of two different kinds of the poison, one very virulent, the other very feeble.

Influence exerted on the Bacterium of Splenic Fever by Subjects refractory to it.*—M. A. Chauveau has tested this question by taking sheep which were known to be naturally refractory to the poison, and reinforcing this natural inaptitude by inoculating, so as to produce almost complete protection, and then injecting infected blood into their circulation in large quantities. Thus eight sheep were subjected to several preliminary inoculations by hypodermic injections, three of them having, besides, 1 c.c. of infected blood injected into the

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* Comptes Rendus, xci. (1880) pp. 680-4.

vessels. In the case of five of them the inoculations were made some weeks or months beforehand; the remaining were inoculated only a few days before the final experiment.

The whole eight were then injected with from 15 to 70 c.c. of blood taken from an infected sheep either before or just after death (this amount is said to represent from 12,000 to 200,000 millions of bacilli).

The respiration immediately became very painful, the head was extended, the mouth was opened and foamed, its mucous membrane became cyanosed; a moaning expiration was kept up; sudden panting movements of the sides were accompanied by a very rapid pulse and stupor; defecation was repeated several times, becoming diarrhœal.

On examining the blood of a vessel of the ear for the bacteria fifteen minutes after the transfusion, they are found, but few in number, and fewer than would be the case if the amount introduced were regularly spread throughout the mass of the blood. After from two to six hours they cannot be found at all.

Of the sheep thus treated one developed true splenic fever, and died after the unusually short period of about sixteen hours. It was one of those which had been vaccinated but shortly before the experiment, and had received the maximum quantity of infected blood, viz. 70 c.c. Another, which had been inoculated five times previously, and received 65 c.c. of infected blood, also died in twelve hours, but not of true splenic fever, for the bacteria did not grow, and two hours after death scarcely any trace of them was to be found. Four of the other sheep also died in from forty-six to 100 hours, not of the splenic disease, but from a purely local proliferation of the bacteria, viz. in the pia mater, which gave rise to meningitis. The bacteria were scarcely to be found in any of the parenchymatous organs (lungs, spleen, &c.) after death, but they occurred in great abundance in the vessels of the pia mater and their sheaths, showing the peculiar characters of being long, bent, or twisted, and sometimes containing spores. They produced an inflammation which sometimes extended over the brain, and even into the ventricles. No pus was formed. The bacteria found here were strongly infectious, rapidly killing subjects inoculated with them, while blood from other parts of the body failed entirely to produce that effect. The two remaining sheep recovered entirely, and furnished good meat, which was eaten.

The chief conclusions which are deduced from these experiments, with regard to the action of bacteria in such cases, are:—(1) The bacilli introduced into the circulation rapidly disappear from the blood. (2) The reason of this fact is not that they are destroyed, but that they are detained in some of the parenchymatous organs. (3) When the subject survives the operation more than three days, they disappear even from the organs mentioned, and health is restored. (4) To the unsuitability of the organization of such animals for the growth of the bacterium the surface of the brain is a marked exception, but the growth in this case has characters never observed in living animals attacked by true splenic fever. These characters are, however, presented by the bacteria of cultivating solutions, and, under certain conditions, in blood of animals after death.

Further Observations on the Etiology and Prevention of Anthrax.*—M. Pasteur quotes a note relating to anthrax written by a former ambassador of Saxony at Paris (Baron Seebach) to M. Tisserand, as long ago as 1865, as remarkably confirming the conclusions recently arrived at as to the nature of the disease.

This note states that on the land belonging to the writer a tenant began in 1845 to introduce improvements in the cultivation. With that view he selected as soil suitable to be spread over the ground used during the winter for cattle-pens—which was destined again to be removed, after being enriched by the presence of the beasts, to form manure—the earth from a strip of land which had been for years used to bury carcases in. This soil was spread over half the space of the pens, and on this half nearly 900 oxen were placed. The sheep were placed close to them, and the rest of the oxen at the other end. A few days after this, in one night two of the oxen died, and the next day six more were lost. On the following morning forty-five were found dead, besides a sheep in the neighbouring enclosure. The loss continued. At last the earth was removed, the enclosure cleaned out, and a layer of rubbish a foot deep was spread over the pens. For eight days the losses continued the same, and then began gradually to diminish. In the first fifteen days 312 oxen had perished in the enclosure covered with the removed earth, and eight sheep belonging to the neighbouring pen. No deaths occurred in the enclosure which was separated from the fatal spot. In the spring the sheep were turned out to pasture on land manured by earth taken from the place where the sheep which had died in the winter had been buried. In eight days thirteen of these sheep died, although the soil had been well turned, exposed to the air and frost, and mixed with lime and ashes; and of ten more which were confined here as an experiment three died in three days. The shepherd had a belief that certain fields were unhealthy and not fit for the sheep to pass the night upon. A field in the corner of which a sheep had been buried was sown with wheat, and the next year with clover, which grew with great luxuriance in the spot mentioned. Some of the clover was taken from the spot by a neighbouring woman, who fed her goat and cow with it. The next morning the cow had a decided attack of anthrax, and the goat had already died from the same disease. Hence the germs—derived from the dead sheep—had been transmitted through the clover after nearly two years. After this the plan, hitherto adopted, of burying dead cattle in shallow graves on the pasturages was abandoned for that of having a special place well divided off and set apart for the purpose, with the result that whereas previously to this step the loss of animals had been from 15 to 20 per cent. per annum, the average was only 7 per cent. for the five years following, and after two years had fallen to 5 and three years later to 3 per cent.

While comparing these facts with those obtained recently by confining sheep over the grave of an animal which had died of the disease, and by experimenting on animals with the earth and worm casts from the same place, M. Pasteur mentions an experiment lately performed by him, in co-operation with M. Chamberland, which is a modification

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* Comptes Rendus, xci. (1880) pp. 697–701.

of that first mentioned by virtue of the addition of cut barley-spines to the food of the sheep, which was sprinkled on the soil covering the graves; in this instance two, instead of one, out of four sheep died. The tendency of the rough fibre to irritate the mucous membrane and facilitate the action of the germs is paralleled by the apparently similar action of stubble, which is shown by the increase of mortality among sheep when placed among it.

Intravenous Injection of Symptomatic Anthrax as a means of Immunity.*—Messrs. Arloing, Cornevin, and Thomas, referring to this disease, which has lately been described by them as distinct from anthrax proper, state that it differs from that disease in producing merely discomfort, with want of appetite and slight fever, lasting from one to three days, when simply injected in solution into the jugular vein (in the calf, sheep, and goat). On testing the animals thus injected from five to twenty days previously by inoculating the muscles with the bacterium, it was found that no anthracic tumour was produced, but merely an abscess containing the bacterium in an active state. Thus an immunity against the disease is conferred by intravascular injection, but it must be performed some days beforehand, or the subject will die. It appears that one injection will mitigate the minor effects of a second one, and the more numerous the injections the greater is the success which is attained in this respect.

Algæ.

Algæ of the Hercules Warm Spring.†—Dr. K. Mika enumerates the following as the algal vegetation of the well-known warm spring of the Hercules Bath, near Mehadia, viz. 19 species in all, including 5 of *Oscillaria* and 4 of *Beggiatoa*. In the spring itself only those species can exist which are characteristic of sulphuretted water; in the outflow these are mingled with species which thrive in water containing putrescent matter.

Trichogyne of Hildebrandtia rivularis.‡—M. P. Petit thus describes the female reproductive organs of this alga, which covers the stones of the public fountain of Morsang-sur-Orge. At the end of June each year certain cells develop into long hairs, altogether resembling the trichogyne of other Florideæ. In the depressed parts of the thallus, where the filaments are shortest, consisting of six or seven cells, thickest, and of a pale red colour, a small mass of gelatinous matter is developed, when the filaments soon detach themselves from the stone, and spread in the gelatine. In one of these cells a small protuberance then makes its appearance, which develops rapidly in the course of the next few days, and assumes the form of a hair full of refrangible matter, of a light rose colour, and containing granules and vacuoles. As the plant does not here produce antheridia,

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* Comptes Rendus, xci. (1880) pp. 734–6.

† 'Magyar növéntyani Lapok,' iv. p. 85. See Bot. Ztg., xxxviii. (1880) p. 745.

‡ Bull. Soc. Bot. France, xxvii. (1880) p. 194. Brebissonia, iii. (1880) pp. 1–5 (1 pl.).

the impregnation of the trichogyne and formation of the cystocarp could not be followed out. After some time the gelatine disappears, and the filaments are carried away in the current of water.

Plurality of Nuclei in the Siphoneæ.*—G. Berthold confirms the observations of Schmitz † relative to the presence of a number of nuclei in the cells of several Siphoneæ belonging to the genera *Codium*, *Derbesia*, and *Bryopsis*. In *Codium* he has been able to follow the process of division of the nucleus. It first assumes a fusiform shape, then becomes constricted in the middle, while the ends swell out, and finally separate as the two daughter-nuclei, the threads which separated them becoming ruptured and disappearing. In *Derbesia* there are a number of nuclei in the young sporangia, united to one another by a network of threads. As development advances these are replaced by a much smaller number of larger nuclei, which are at first not sharply defined; round each of these a zoospore is then formed.

Conjugation of Zoospores in Dasycladus.‡—The discovery by de Bary and Strasburger of the conjugation of zoospores in *Acetabularia mediterranea* induced G. Berthold carefully to examine with the same object *Dasycladus clavæformis*, which fructifies abundantly in the Bay of Baiæ.

The large spherical sporangia stand singly at the apex of the verticillate branches, surrounded by the branchlets of the second order. They are attached to the branch by a short slender pedicel, through which the protoplasm enters the fructifying plant, so that the latter is almost colourless, with the exception of a great number of dark green dots. When all the protoplasm has entered the fertile part, the opening of the pedicel is shut off by a brown septum. The protoplasm forms in the sporangium a thick opaque parietal layer, which breaks up into the separate zoospores. These escape through a crevice, and immediately move about actively in the surrounding water; accompanying them are a number of granular bodies, and the peculiar yellowish-brown colouring matter of *Dasycladus*. The zoospores have a greatly flattened and heart-shaped form. Two long cilia are attached to a short protuberance in the centre of the anterior broader side. They have a clear space or nucleus but no pigment-spot. In the vegetative plant are a large number of nuclei.

Zoospores from the same plant showed no disposition whatever to conjugate; but as soon as those from different plants were brought together conjugation took place at once, showing that they are true zygospheres (gametes of Strasburger). A number however remained without conjugating, and soon perished; while in a few cases an aggregation of a number was observed, as in *Acetabularia*. The conjugation takes place by the union of the flat or also of the narrow sides, the coalescence commencing in the middle, and advancing then in both directions. During and after conjugation the zygospheres

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* MT. Zool. Stat. Neapel, ii. (1880) pp. 72–8. See Bot. Ztg., xxxviii. (1880) p. 701.

† See this Journal, iii. (1880) p. 493.

‡ Göttingen Nachr., 1880. See Bot. Ztg., xxxviii. (1880) p. 648.

swarmed actively, not coming completely to rest in some cases for sixteen hours. The resulting zygosperm (zygote of Strasburger) then rounds itself off, and begins to germinate. No morphological differentiation whatever could be detected in the zygospheres before conjugation.

Sexual Reproduction of the Bangiaceæ.*—The statement of Reinke that in these Algæ the amœboid spores are impregnated by the spermatia, has been shown to be incorrect by Goebel. G. Berthold has now followed out the process of fertilization more completely.

The small spermatia (pollinoids), which have long been known in the case of *Porphyra*, attach themselves singly or in numbers to the surface of the thallus, over the centre of the cells. At first spherical and membraneless, they become somewhat flattened, and, while closely adherent to the thallus, become coated with a delicate cell-wall. By means of a slender thread of protoplasm they then bore through the cell-wall of the thallus, nearly the whole of the contents passing into the cell. The result of this impregnation is that the contents of the cell break up into eight spores (oosperms), which move about, on escaping, in an amœboid manner. In some cases the female cells (oogonia) put out on both sides trichogyne-like protuberances, the contents of which are used up in the formation of the spores.

The author has also seen non-sexual spores of *Porphyra*, somewhat larger than, but otherwise resembling the oosperms.

These observations induce Berthold to assign the systematic position to the Bangiaceæ as the lowest class of Florideæ. From *Bangia* and *Porphyra* there is a gradual transition through *Balbiana* and the Nemalieæ to the typical Florideæ, and the peculiar structure of *Lemanea* and *Dudresnaya*.

Cladothrix and Sphærotilus.†—In the sediment of vessels containing water, B. Eyferth found abundance of filaments of *Stereonema* Ktz., mixed with stems of *Anthophysa*. The tubular *Stereonema* filaments were covered with threads, which broke up at the extremities partly into bacteroid fragments, and partly manifested false dichotomous branching. These were identified with *Cladothrix dichotoma* Cohn; and the author states that between this and *Sphœrotilus natans* Ktz. there is a complete series of intermediate forms, although the extreme forms differ greatly, depending on an abundant or defective supply of nutriment. The *Sphœrotilus* is an extremely useful organism in purifying impure water.

Sycamina nigrescens, a Volvocinea destitute of Chlorophyll.‡—M. Van Tieghem has examined the black or dark deposit found on the surface of pond-water or at the bottom of aquaria, and finds it to be composed of a minute blackish alga, destitute of chlorophyll, and living on the organic matters the decomposition of which it promotes.

In its mature condition this organism consists of minute spherical

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* MT. Zool. Stat. Neapel, ii. (1880) pp. 78–82. See Bot. Ztg., xxxviii. (1880) p. 701.

† Bot. Ztg., xxxviii. (1880) pp. 673–6.

‡ Bull. Soc. Bot. France, xxvii. (1880) pp. 200–4.

cells, hundreds or thousands of which are associated together into a spherical mulberry-like mass, but not enclosed in a gelatinous envelope. The cells are not more than 2 μ in diameter, but are provided with a relatively thick hyaline membrane, enclosing a black or chocolate-brown protoplasmic body. A pair of vibratile cilia pass through the membrane, and the whole mass is in active motion, revolving round its centre. In some cases the cilia have disappeared, and the mass has become immotile. The mass measures 8–10 μ in diameter when it consists of about 100, 30–40 μ when it consists of 1000 cells. Beyond this size it elongates into an oval form, becomes constricted in the middle, and then divides into two, both freely endowed with motion. There is no chlorophyll in the cells. Placed in sunshine in water containing carbonic acid they do not disengage carbonic acid. They sometimes assume a violet or reddish colour.

Besides the division of the mass, there are two other modes of multiplication. When the mass has attained its full size, the cells of which it is composed sometimes completely separate from one another; those at the periphery, which have retained their cilia, continue to move about, while those towards the centre, which have lost their cilia, are motionless; while in other cases all the cells are motionless. Each cell then multiplies into two by the ordinary process of cell-division; and the process is indefinitely repeated. The daughter-cells sometimes separate completely after each division; sometimes they gradually aggregate into a mulberry-like mass. The colour of the protoplasm is dark or light blue or dark brown.

The third mode of multiplication takes place by the thick membrane of the separate cells becoming gelatinous, and gradually dissolving; the protoplasm remaining in the form of highly refractive colourless spheres or resting-cells. Under favourable conditions they increase in size, a dark blue pigment becomes gradually diffused through the protoplasm; they become invested with thick membranes, and provided each with two cilia. Under the form of resting-spores the organism can pass through periods of drought or cold.

As regards the systematic position of this organism, it seems to present the greatest affinity with the Volvocineæ, notwithstanding the absence of chlorophyll, and especially with the three genera, *Synura*, *Syncrypta*, and *Uroglena*, established by Ehrenberg, characterized by the presence of a special colouring matter which masks the chlorophyll. Van Tieghem proposes to establish for it a new genus, and to call it *Sycamina nigrescens*. It occurs at the bottom of water in ponds and vases in the midst of organic detritus, and disengages a large amount of marsh-gas.

Glœocystis.*—This organism has been described by Naegeli as belonging to a low type of organization; by Cienkowski as nearly allied to the Volvocineæ, and by Lohde as exhibiting affinity with the Hydrodictyeæ. P. Richter, who has submitted it again to a close examination, agrees with the first view, considering that the two latter authors had under observation, not the true *Glœocystis*, but a condition

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* Hedwigia, xix. (1880) pp. 154–9.

of some higher organism enveloped in a coat of mucilage, as is the case with detached cells of *Draparnaldia*, the resting condition of *Chlamydomonas*, &c.

In gelatinous masses fresh collected from rocks, moss, &c., Richter found, mingled with *Glœocystis rupestris*, pale, star-shaped, and again green spherical spined cells with a firm cell-wall, from 8 to 10 μ in diameter, which he regards, with some hesitation, as its resting-spores. He considers also *Glœocapsa monococca* and *stillicidiorum* Ktz. rightly to belong to the same cycle of development as *Glœocystis vesiculosa*, and *Palmoglœa lurida* and *rupestris* to belong to *G. rupestris*.

The contents of young active cells is uniformly distributed through the cell-cavity, and is finely granular; or is sometimes accumulated on one side of the cell, the other half containing only a pale bluish protoplasm. The cells are elliptical, often somewhat pointed at one end, varying in length from 7 to 12 μ, and in breadth from 4 to 8 μ. The cell is usually surrounded by a cylindrical envelope of jelly; but this is often so delicate as only to be detected when dry. In other examples again, the chlorophyll occupies only one-half of the cell-cavity, and is bounded by a diagonal line. In others, the chlorophyll-mass has somewhat the form of a horseshoe or kidney.

In individuals in which the contents are evenly distributed, and which are also somewhat swollen, a division takes place into four roundish or elliptical parietal balls, which soon develop into elongated ovoid bodies and fill up the entire cavity. Usually the common envelope then bursts, and the daughter-cells escape and go through the same process again; or the envelope expands into a spherical or cylindrical form, till it has reached 17, 19, or even 30 μ in length, enclosing two generations of daughter-cells. The daughter-cells do not always acquire special gelatinous envelopes, but sometimes lie free in the common envelope. Sometimes there appears what looks like an arrested production of swarm-spores.

The cylindrical form is identified by the author with *Glœocapsa monococca* Ktz.; the subsequent division and formation of daughter-cells within the common envelope results in the production of *Glœocystis vesiculosa* Naeg. This sometimes assumes a Palmella-condition, and is then *Glœocapsa stillicidiorum* Ktz. The formation of special envelopes ceases, the daughter-cells lie free in the common envelope, and divide repeatedly in tetrahedra, thus forming mulberry-like colonies, the common envelope having by this time deliquesced. The separate finally spherical cells vary greatly in size; they were measured between 3 and 7 μ in diameter. From these again at length the *Glœocystis*-form was developed, special vesicles assuming again a cylindrical form. In this generation the author noticed a process which might be a rudimentary and uncompleted act of conjugation.

According to these observations, therefore, *Glœocystis* has a form of development consisting of cylindrical cells, which may be encysted or free, and which alternate with the familiar spherical encysted form; a palmella condition with tetrahedral divisions occurring also within the latter. The first form may be termed the *Cylindrocystis* condition. Each of these forms may be developed from another; and *Glœocapsa*, *Cylindrocystis*, and *Microcystis* must be regarded as probable synonyms of *Glœocystis*.

Chromophyton Rosanoffii.[*] — Under this name M. Woronin describes a very peculiar and interesting organism which he finds in the form of a fine light yellow or brown dust on the surface of pools in boggy districts in Finland. On warm, still, and sunny days the surface of the water became completely covered with this dust, which disappeared as soon as the weather became rainy. When removed into a glass vessel, if the water is well shaken it becomes perfectly clear; but the surface is soon covered with the yellow coating if left standing in a room. If sprinkled with water, it also disappears, as under the influence of rain. It will remain, however, on the surface of the water in the vessel through the autumn and winter, when it has completely disappeared in the open.

If a drop of water covered with the yellow dust is carefully placed on the slide so as not to moisten the dust, and without a cover-glass, it is seen that the particles which compose it project above the surface of the water in a variety of forms. The smallest are always spherical, and from their sharp and usually very dark outline, appear like little drops of oil or bubbles of air, but are distinguished from the latter by a light yellow glistening. The larger particles are spherical, hour-glass-shaped, moniliform, or vermiform; and the largest of all have extremely irregular forms. The larger particles appear to consist of a colourless hyaline mucilaginous matrix, in which are imbedded several irregular, rounded or ribbon-shaped, yellow bodies having the appearance of flakes. The application of a higher power shows these yellow particles to be so many zoospore-like bodies, each of which is provided with a yellow pigment-spot. Occasionally they have a slow power of motion within the matrix.

That these bodies are true swarm-cells is at once shown by placing a cover-glass on the dust. As soon as the particles become thus immersed in the water, the colourless mucilaginous matrix swells up violently, and the imbedded zoospores are set free, and at once begin to move about actively. They are uniciliated, and consist of a colourless, somewhat elongated, irregularly ellipsoidal protoplasm-body, which is generally rounded at both ends, very rarely narrowed at the ends, and has an average length of about 8–9 μ, and breadth of 4–6 μ. Much less often it is nearly spherical. At one side of the anterior half of the zoospore is a yellow or bright yellow-brown pigment-plate, apparently of similar composition to the diatomin of the Bacillariaceæ. Heat or acetic or dilute sulphuric acid usually induces a greenish colour in the dead zoospore. In the colourless protoplasmic portion of the anterior half of the zoospore are several small granules and one or two vacuoles, one of which is always contractile. The colourless protoplasm of the posterior half is much more refractive, and has more or less resemblance to a drop of oil. The cilium and its point of attachment are revealed by treatment with iodine, which causes the zoospore to become spherical with its cilium stretched out straight.

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[*] Bot. Ztg., xxxviii. (1880) pp. 625–31 and 641–8.

The movements of the zoospores in water are greatly influenced by light, collecting towards the source of light beneath the cover-glass, and even moving towards it with great rapidity. If the cover-glass is removed they swim upon the surface of the water in a very peculiar way. The zoospore dips beneath the surface of the water, comes to rest, rounds itself off, and then bores through the surface as if it were a solid membrane, by means of a protuberance which thus elevates itself in the air, and gradually increases in size as the part below the surface diminishes, and finally disappears, so that the zoospore is now entirely exposed. This process recalls the mode in which the zoospores of the Chytridiaceæ penetrate the tissue of their host. A close examination shows that during this process the zoospore has enveloped itself with a delicate colourless envelope of gelatine, which has a tubular opening below through which the zoospore absorbs water.

If left for a time undisturbed on the surface of the water, the encysted zoospore begins to multiply by bipartition, 2, 4, or 8 cells being formed within the common envelope, the entire organism varying in size according to the number of enclosed cells. These constitute the yellow dust with which the observation started; the larger particles being formed by the coalescence of a number of the gelatinous envelopes of smaller particles, as can be readily followed step by step under the Microscope. Not the least trace of a union or conjugation of the individual zoospores within the envelope can be made out. Each individual, moreover, retains its tubular projection beneath the surface of the water; the number of these being therefore large in the larger particles. These tubes are, however, only clearly seen when the particle is immersed in water, being of a firmer consistency and not swelling up like the rest of the envelope. As soon as the swelling has taken place, the zoospores escape into the surrounding water, and begin to move about actively. They soon move towards the light, and reaching the surface of the water, go through the same process again.

On some of the pools was found also a coating of a much finer dust, a microscopical examination of which showed it to be of precisely the same composition as the coarser. The swarm-cells are extremely minute, always spherical, uniciliated, and provided with one or two pigment-spots of a pale brown or greenish-yellow colour. The author was unable to determine with certainty whether these are an independent organism, but inclines to the view that they belong to the same cycle of development as *Chromophyton Rosanoffii*.

Great interest attaches to the wintering of this organism, which takes place within the leaves and stem of *Sphagnum*. It is well known that various lowly organized Algæ, such as *Nostoc*, *Anabœna*, *Oscillaria*, *Chlorococcum*, &c., are found within the large empty cells of *Sphagnum*; the peculiarity of the *Chromophyton* is that it enters not only these, but also the small cells between them, through the cell-wall of which they must bore their way, but apparently only in those which no longer contain chlorophyll. It chooses also other aquatic mosses, as an undetermined species of *Hypnum*, for its winter quarters, but here again only the cells destitute of chlorophyll.

Within the host, although no cilia are yet to be seen, the *Chromo-*

phyton is endowed with an amœba-like motion, and the vacuoles pulsate. They are at this time still naked; but they soon round themselves off, come to complete rest, and appear to clothe themselves with a delicate cell-wall. They multiply by repeated bipartition, so that the cells of the host become sometimes completely filled by them. They then assume a somewhat angular form, and may be regarded as cysts or resting-spores. In them the whole contents of the cells appears to have a brownish-yellow colour, with the exception of some colourless portions, which may be oil-drops or nuclei.

In addition to these, there was found in the large cells of some dying *Sphagnum* leaves, a second form of resting-spore, larger in size, perfectly spherical, with a much firmer and often double membrane, and only half-filled with the yellow pigment. Similar structures are also sometimes found outside the leaves of the host. Some of them also present a double appearance, the result either of coalescence in growth or possibly of conjugation. The author has succeeded in developing the motile form of *Chromophyton* from these resting cysts.

With regard to the systematic position of *Chromophyton*, nothing can yet be said with certainty. Many of the points described appear to indicate an alliance with the Palmellaceæ. It also presents great similarity to an organism described by Cienkowski under the name *Chromulina nebulosa*, as belonging to the Flagellata Infusoria.

Norwegian Desmids.[*]—The first part of a paper by N. Wille, on the fresh-water Algæ of Norway, is devoted to the Chlorophyllophyceæ of Smaalehnen, a boggy and mossy district lying east of Christiania Fjord, with a substratum of granite or gneiss. He describes in all 224 species of Desmidieæ, belonging to 18 genera. Among them are 5 new species of *Cosmarium*, 1 of *Arthrodesmus*, 2 of *Staurastrum*, and 3 of *Closterium*, besides 1 of *Ulothrix* (*Hormospora*). He also enumerates in the same district 13 species of Tetrasporeæ, 13 of Pediastreæ, 3 of Characeæ, 2 of Protococcaceæ, 6 of Volvocineæ, 4 of Zygnemeæ, 3 of Mesocarpeæ, 1 of Ulvaceæ, 5 of Confervaceæ, 3 of Ulotrichaceæ, 1 of Chroolepidæ, 8 of Chætophoraceæ, 3 of Vaucherieæ, 23 of Œdogoniaceæ, and 4 of Coleochæteæ.

Movements of Diatoms.[†]—M. C. Mereschkowsky considers that, although this subject has been specially attractive, no one has hitherto succeeded in furnishing a positive explanation of the phenomenon. The nature of the forces brought into play, and the utter want of direct positive facts which could be taken as the basis for an explanation, resulted in hypotheses supported only by indirect proofs, and for that reason as unsound as they were short-lived.

Two hypotheses are extant. The first, which has had for its advocates Max Schultze,[‡] Pfitzer,[§] and, recently, Engelmann,[||] sup-

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[*] Forhandl. Vidensk. Christiania, 1880, pp. 1–72. See Bot. Ztg., xxxviii. (1880) p. 745.

[†] Bot. Ztg., xxxviii. (1880) pp. 529–40 (3 figs.).

[‡] "Die Bewegungen der Diatomeen," Arch. f. Mikr. Anat., i. (1865) p. 385.

[§] 'Untersuchungen über Bau und Entwickelung der Bacillariaceen,' 1872, p. 177.

[||] "Ueber die Bewegungen der Oscillarien und Diatomeen," Bot. Ztg., xxxvii. (1879) No. 4.

poses that the cell of the diatom, which contains a deposit of protoplasm, sends out processes or laminæ through the pores in the cell-wall, or through the suture which separates the two halves. These processes of the protruding protoplasm (or, it is even said, a thin layer completely enveloping the alga) are considered to produce by their contractility all the phenomena of motion. Schultze and Engelmann have recourse to the following indirect arguments:—

(1) They maintain that these movements only take place when the algæ touch some fixed object with the suture; * when, on the contrary, they swim free in the water no motion is observed. Without the assumption of an envelope of protoplasm this phenomenon is, in their opinion, quite inconceivable.

(2) Von Siebold and M. Schultze's observations are adduced, according to which indigo and carmine particles when they touch the suture remain attached to it, and begin to move backwards and forwards in its direction, just as grains of chlorophyll do in the protoplasm of the cells of *Vallisneria*.†

Besides this, the diatom not unfrequently draws after it a cluster of grains of sand, &c., sometimes of very considerable dimensions. This cluster has no connection with the posterior end of the cell, but is at a greater or less distance from it. These authors therefore consider that probably an invisible thread of protoplasm connects the cluster with the alga and draws it after it.

(3) An external layer of protoplasm is said to have been recently discovered, which envelops the threads of *Oscillariæ*, and produces various motile phenomena. From analogy it may be assumed that the Diatomaceæ are also surrounded by a similar external layer; and this, it is alleged, explains all the phenomena of motion in the Diatomaceæ, and the more so since they are very similar to those of the *Oscillariæ*.‡

Other botanists, such as Naegeli,§ Dippel,‖ v. Siebold,¶ Raben-

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* Borscow says, "The movement is quite independent of the relative position of the cells. M. Schultze (l. c., p. 385) is decidedly wrong when he maintains that the cells of Bacillariaceæ only exhibit movements when they lie on the valve side, where, according to M. Schultze, the raphe or suture is. The best proof of this is furnished by such forms as *Cylindrotheca* and *Nitzschiella*, which besides the motion backwards and forwards in the direction of the longitudinal axis of the cell, revolve at the same time round the axis, and consequently must be alternately sometimes on the valve surface and sometimes on the hoop surface" (l. c., pp. 35–36).

† Borscow has besides already pointed out that on touching any other part of the diatom carmine-particles assume a gliding movement. See Borscow, 'Die Süsswasser-Bacillarien des südwestlichen Russlands,' 1873, p. 36.

‡ As regards Engelmann's observations on the layer of protoplasm enveloping the threads of Oscillariæ, they seem to the author to be far from satisfactorily proving such an assumption. On applying an induction-current or strong sulphuric acid Engelmann saw surrounding the whole alga a distinct though very fine envelope with a double contour. This envelope dissolved in a weak alkaline solution, in hydrochloric acid, and in a 10 per cent. solution of common salt. Our knowledge of the chemistry of mucus products is however as yet too imperfect to allow us to exclude with certainty the idea that the process described was owing to something else than protoplasm (e. g. mucous cellulose).

§ 'Beiträge zur wiss. Botanik,' 2 Heft, 1860, pp. 90–91.

‖ 'Beiträge zur Kenntniss der in den Soolwässern von Kreuznach lebenden Diatomeen,' 1870, p. 32.

¶ "Ueber einzellige Pflanzen und Thiere," Zeitschr. wiss. Zool., i. (1849) p. 284.

horst and Borscow,* advocate another hypothesis. According to their view the chief cause of all movements of *Bacillariæ* is the energy of the osmotic processes. The proofs which they adduce are likewise indirect, and consist essentially of the following:—

(1) In the first place, no one has seen in the Diatomaceæ either pseudopodia, or in general any external protoplasm. The supposed extreme fineness of the former is not a valid reason for not seeing them, as the very fine pseudopodia of some Protozoa are plainly seen without the use of reagents. The invisibility of the external protoplasm is also the more extraordinary, as it has been sought for by such practised microscopists as Max Schultze, Cohn,† Pfitzer, and Engelmann.‡

The (in the opinion of the author) most doubtful existence of an external protoplasmic layer in the Oscillariæ, were it even actually confirmed, affords no solid grounds for assuming such a layer to be present in the Diatomaceæ.

(2) Another objection may be urged against the protoplasm theory. The character of the movements does not at all suggest those of such organisms as make use of either the contractility of the protoplasm *en masse*, or that of the pseudopodia. In the diatoms we do not see the uniformity and sluggishness characteristic of the former, but on the contrary, the movement not unfrequently takes a backward direction, so that the alga sometimes goes back suddenly a comparatively great distance.

As an illustration, the author adduces the description of this phenomenon given by Borscow.§ "The cell, until then round," he says, "*suddenly* makes an energetic rectilinear forward movement, stops for a time, and after this short pause makes a rapid movement straight as an arrow in the opposite direction, whereupon a pause again ensues." In other cases we may "observe that several forward movements of the cell, broken by short pauses, follow one another; then ensues a longer state of rest, and subsequently a retrograde movement takes place in the same manner, i. e. *by jerks*."

Nothing similar to this is found in the *Amœbæ*, and other Rhizopoda, or in the plasmodia of Myxomycetes, on their changing their locality.

Regard must also be had to the fact that a diatom in moving is frequently not in a horizontal position, but keeps one of its ends directed somewhat upwards, so that the supporting surface is in contact with its other end only, consequently with a very inconsiderable portion. It is difficult to conceive how so small a quantity of protoplasm which touches the surface in such a case could put in motion by its contraction not only the whole (sometimes large) cell, but also a considerable number of foreign bodies, such as grains of sand, &c., which often cling to the alga.‖

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* 'Die Süsswasser-Bacillarien des südwestlichen Russlands,' 1873, p. 34.

† "Beiträge zur Physiologie der Phycochromaceen und Florideen," Arch. Mikr. Anat., iii. p. 50.

‡ Bot. Ztg., loc. cit., p. 55.

§ Loc. cit., p. 35.

‖ This elevation of one end of the alga is easily explained by assuming that the specific gravity of it fluctuates about 1, and in favour of this the fact may be

(3) The main proof of the first hypothesis consists in this, that for the motion of diatoms their contact with some fixed body is indispensable. This can only claim to be indisputable on its being ascertained that a floating diatom does not move at all. Up to the present, however, we know of no method for the observation of diatoms under such conditions, and consequently this suggestion is for the time incapable of being supported. We may suppose that the movable alga clings to the bottom, because (1) as a heavier body it at once sinks, and (2) that having got there, it adheres to the substratum by means of some glutinous substance (as a mucous external cell-membrane). This adherence is anyhow not so firm that it renders it impossible for the osmotic forces to move the cell. Therefore, the facts described might be explained simply and naturally, without the assumption of any invisible protoplasm. And the probability of this explanation is increased by the fact that amongst plants a number of analogous phenomena—that is, examples of adherence of the cells by reason of the local or general mucous condition of their walls—is known to exist. That the Diatomaceæ form mucus is borne out by the observations of Borscow :—"The living cells of many species of *Cocconeis*, *Navicula limosa*, and *Frustulia* appear under very exact focussing to be bordered by a substance as transparent as glass, and having a sharp outline. The observations were made with Hartnack's best objectives, and the possibility of aberration phenomena was not lost sight of."*

A similar, and, in addition, temporary adherence is seen with some free-living animals, as Rotifera and Infusoria, e. g. with *Ervilia monostyla* † and *Tintinnus inquilinus*,‡ in which the phenomena depend upon the bottom of the test of the animal becoming mucous.

The same mucous condition may very well explain the adherence of foreign bodies to Diatomaceæ. The adherence casually observed is by no means restricted to the suture, but takes place over the whole surface of the alga.§ In the same way, on this view of the matter, the trailing of sand-grains is easily understood; fine transparent threads of mucus which proceed from the external mucous layer of the cell, explain this connection of the grains much more simply than any protoplasmic threads or pseudopodia.

When we weigh what has been said, and compare the proofs which the two parties adduce, it is found that almost all the (indirect) proofs adduced in favour of the protoplasm theory are met successfully by the opponents. We cannot therefore regard the second, or osmotic,

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quoted that some Diatomaceæ are specifically heavier than water, therefore sink to the bottom; others, on the contrary, are lighter, and consequently swim. The physico-chemical processes of which the life of the cell is composed, since they alter somewhat the specific gravity of the alga, can by reducing it impart an impulse upwards, as the result of which one end of the alga may be raised from the ground, and thus its horizontal position is changed into an oblique one.

* Loc. cit., p. 41.

† Dujardin, 'Infusoires,' p. 455.

‡ C. Mereschkowsky, 'Studien über Protozoen des nördlichen Russlands,' 1878, p. 20.

§ Borscow, loc. cit., p. 42.

theory as being less well founded and probable than the first. If we also take into consideration that the osmotic theory does not require the assumption of any external protoplasm which no one has yet seen, it has a certain advantage over the other.

The author then proceeds to describe the *direct* observations made by him which he considers prove that osmotic phenomena are the cause of the movements of the Diatomaceæ.*

"In January 1879, being mainly occupied in zoölogical investigations at the zoological station of Naples, I had an opportunity of observing three species of Diatomaceæ, which are very common in the sea there. They were two species of *Navicula* (one a very large kind) and a *Stauridium*. A vessel of sea-water containing algæ from the shore, after standing for some days and acquiring an offensive smell, showed a number of the smallest micrococci, amongst which, in a drop taken from the bottom, a considerable number of the above Diatomaceæ were swimming.

With regard to their motion the following particulars were observed:—

(1) The usual motion backwards and forwards, with intervals of rest. The algæ always lay not horizontal but obliquely, so that one end touched the slide whilst the other was somewhat raised.

(2) Besides a rectilinear motion, a lateral rotation of the whole alga was observed, the raised end describing a circle whilst the other, which adhered to the slide, occupied the centre.

Pursuing my observations further in this direction, I noticed the following attendant phenomena:—

(1) First a violent vibration of the micrococci in the immediate neighbourhood of the living diatom, whilst the others, lying farther from it, or near to the dead ones, or to other foreign substances—sand-grains, &c.—displayed no such violent movements.†

The vibration was most violent in the micrococci nearest to the diatoms. They threw themselves from one side to the other in a very regular fashion. The more distant the micrococci were from the algæ the slower their movement was, and finally it ceased altogether at a certain distance (about half the length of the diatom). In this way a living diatom appeared to be surrounded by a perfect sphere of micrococci, vibrating more or less.

This phenomenon justifies the conclusion, not only of the existence of osmotic forces, but also that they possess considerable intensity.

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* [The author makes no mention of English observers, but it may be pointed out that the suggestion that the movements of diatoms are caused by exosmose and endosmose, was made by W. Smith in 1853. Cf. 'Synopsis of the Diatomaceæ,' i. (1853) Introduction, pp. xxii.–iv. See also the objections of the editors of the 'Micrographic Dictionary,' 3rd ed. (1875) p. 237; Dr. Carpenter's reply in 'The Microscope and its Revelations,' 5th ed. (1875) pp. 318–19. The object of M. Mereschkowsky's paper is to give a *direct proof* of the fact.—Ed. J. R. M. S.]

† Although I do not now remember the fact, and find no mention made of it in my notes, yet I think that probably all the micrococci were displaying the so-called molecular or Brownian movement. At all events this latter, on account of its feebleness compared with the strong and violent vibration of the micrococci under the circumstances described above, would be unimportant.

(2) Further, I was able to establish the fact that there is a very noteworthy difference in the oscillation of the micrococci according as the alga is at rest or in motion. As long as the alga remained quiet all the violently vibrating micrococci were symmetrically arranged (Fig. 1) so that their vibrations ceased at an equal distance all round from the surface of the cell. But an entirely different appearance was displayed by the diatoms in motion (Fig. 2).* Here the dancing was irregularly distributed, the most violent being concentrated at the posterior end † of the alga. At this part it was most energetic, and could easily be seen, even with a low power. Altogether the phenomenon produced the impression as of a violent stream of water behind the moving diatoms, which put the micrococci into irregular motion, and extended a considerable distance (more than the total length of the alga itself). At the same time a very slight movement of the micrococci was noticed at the anterior end; when the pause ensued the vibration again became uniformly distributed, and on the commencement of the retrograde movement the distribution of the vibrating force of the micrococci was reversed. The end where previously they were present in small numbers, moving with feeble oscillation (the former anterior end), showed energetic vibrations, it having become the posterior end; and, conversely, at what was previously the posterior end, where the motions were so energetic, they lost their intensity, and only extended over an inconsiderable space. An invariable connection was always observed between the force of the vibration of the micrococci and the direction of the movement of the alga. The most violent vibration was always seen at the posterior end of the diatom and the feeblest at the anterior end.

Fig. 1.

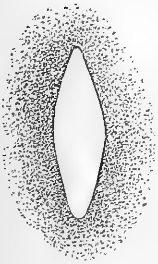


Fig. 2.

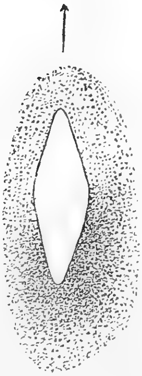
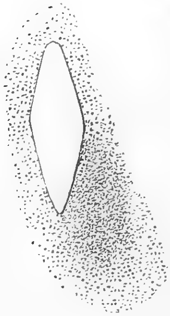


Fig. 3.



This connection points plainly to the fact that the maximum osmose is localized at the posterior end, where the discharge of water

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* The closeness of the dotting denotes the violence of the vibration of the micrococci.

† Relatively to the direction of movement.

or exosmose takes place. At the anterior end, where the micrococci always vibrate more feebly, there ensues the opposite phenomenon—absorption of the water or endosmose, which does not act on the surrounding parts with such force as the discharge of water does at the posterior end.

(3) As already remarked, the vibrating force of the micrococci is distributed uniformly round the cell, when the alga naturally assumes a quiescent state, which always happens after a backward or forward movement. But it sometimes occurs that the moving cell touches some foreign body with its side, and thereby is stopped in its motion, or its anterior end strikes against an insurmountable obstacle. A pause thus artificially produced is not accompanied by any uniform distribution of the vibrating micrococci, but on the contrary, the latter continue to maintain the distribution which they had during the motion, i. e. at the posterior end is seen the most intense and most widely extending vibration, while at the anterior end it is neither so violent nor so noticeable. In the first case the osmotic phenomena evidently occur with equal force at both ends, as the result of which a pause naturally ensues; but in the second case the osmotic phenomena continue to be so distributed that the endosmose is concentrated in front and the exosmose behind. The cause of the motion does not in this case pass away, it is simply paralyzed by an entirely accidental external impediment.

(4) An entirely analogous distribution of the vibrating micrococci also occurs when the diatoms rotate laterally, as mentioned above. In this case the difference is that the strongest vibrations are now noticed on one side of the alga (Fig. 3), on the side from which the rotation proceeds; on the side, however, towards which the motion is directed, the micrococci vibrate much more feebly. Besides this it should be mentioned that the vibration is not evenly distributed on the whole side, but is localized at the free end only (i. e. the free movable end which is not attached to the slide).

(5) That the peculiar way in which the micrococci move is not the result of the motion of the alga itself, and of the current produced thereby in the water, is proved by the fact that the gentlest and slightest movements of the alga, which are incapable of producing in any way such considerable currents, nevertheless bring about the distribution of the micrococci described above, with all their peculiarities which become apparent with stronger movements.

(6) If it were still thought that the strong osmose, the existence of which is now placed beyond doubt, may be only an attendant phenomenon and not the actual cause of the movements observed, such an idea would be refuted by the following fact. It was possible generally, by great attention, to determine beforehand in what direction the movement would take place. A little time (a fraction of a second) before the movement occurred a specially increased vibration of the micrococci could generally be noticed at one end of the alga, and as the result of the observations already described, it is not difficult to foresee that this end is destined to be the posterior, the other the anterior end. This fact, which I had an opportunity of proving

several times, is thoroughly convincing, and establishes with perfect certainty that the cause of the motile phenomenon is the peculiar distribution of the osmose in the cell.

I have thus described all the facts observed by me, which, as I think, must secure for the osmotic hypothesis the decided preference over the protoplasmic.

Taking the above observations as a basis, we may account for the process which takes place in a moving diatom as follows:—In a quiescent cell the phenomena of exosmose and endosmose occur with equal intensity and simultaneously over the whole surface. Before the movement begins the exosmose becomes more intense at one end of the cell than at other parts of it, doubless by reason of the altered density of the cell-contents there, which might happen from alimentary and other physico-chemical processes. This increase of intensity continuing for some time the result at length is that the exosmose (analogous to the effluent water in Segner's water-wheel) sets the diatoms in motion.

The vibration of the micrococci leads necessarily to the conclusion that the exosmose, which, while the cell is at rest, is distributed like the endosmose uniformly over the whole surface, is, on the contrary, concentrated, when it moves, exclusively at one end of the cell: the distribution of the endosmose remains however unchanged. The intensity of the two phenomena, i. e. the quantity of water passing in and out, must be equal to each other; since however the expulsion of the water is concentrated at one end only of the cell, and therefore a small portion of its surface, the action of exosmose naturally displays greater force and extends further. At the rest of the cell surface, where a comparatively feebler and slower endosmose takes place, the motion is less intense and extends to a shorter distance.

If, after all we have said, some are not quite satisfied that the external protoplasmic layer is not the cause of motion, and that the osmotic process is, every one, I think, must be convinced that osmose is one of the causes on which the motion depends."

Grammatophora longissima, Petit.*—Under this name P. Petit described a beautiful diatom from Campbell Island and New Zealand, distinguished by its very long and narrow frustules and by the large number of the undulations of the septa. F. Castracane has now found in Italian waters what appears to be the same species, which he thus describes:—

Grammatophora longissima Pet. var. *italica.* Gr. elongata, sexto-septuplo longior quam lata; dissepimentis 6–7 undulatis, et ad apicem capitatis; valvis curvatis, striis subtilissimis 2900 in millimetro. Frustula usque adhuc inventa in seriem lateralem conjuncta. Longitudo = mm. 0·0585; latitudo = mm. 0·00835–0·00975. Habitat in mari Adriatico et in Tyrreno.

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* Atti Soc. Crittogam. Ital., xxiv. (1881) pp. 25–32.

MICROSCOPY, &c.

a. Instruments and Accessories.

Bausch and Lomb Optical Company's "Professional" and "Investigator" Microscopes.—(1) *Professional.* The description of this instrument was received too late to be inserted in its proper place in order of date, under the head of "Swinging Substages."[*] It appears to have been made in 1876 (Fig. 4, one-third actual size). It is provided with a heavy brass foot, inlaid with three soft rubber pads under the claws. Two solid brass pillars support the trunnion axis on which the limb inclines, and milled screws are on the ends of this axis for tightening the motion. The coarse adjustment is by rack and pinion moving a long prismatic slide attached to the body, and arranged to compensate for wear.

The substage for receiving accessories of English standard size has two revolving diaphragms, one of the latter belonging to the condenser, all attached to the swinging mirror-bar, the axis of which is fixed in the plane of the object, so that the diaphragm and mirror swing concentrically around it. The mirror as well as the substage can be moved on the mirror bar to and from the object, and both can be removed, the latter by a prismatic slide.

Since the figure was made, a modification of the stage-fitting permits the swinging mirror-bar and substage to be swung above the stage for the illumination of opaque objects. An auxiliary ring, with internal "Society" screw is supplied for use in the substage, so that objectives may be used as condensers.

An immersion condenser, mounted in brass, fits either in the stage or substage. It consists of a truncated cone of crown glass, with a convex base, designed to focus the illumination upon the object.

The glass stage and slide-holder are described *infra.*

The chief point of novelty to us is the fine adjustment, which is so simple and effective that we show it in detail in Fig. 5. The drawing of the mechanism is made from Mr. Crouch's stand (Fig. 7) in which the fine adjustment is similar. Messrs. Bausch and Lomb hold a patent for this system of focussing in the United States.

It will be seen that the solid bar A, carrying the optical body B, is suspended on the front ends of the two broad, flat, parallel, tempered steel springs CC, the other ends of which are attached to the limb D. The pressure of the focussing-screw E, by the point at F on the solid bar, forces down this bar, the springs bending sufficiently to allow about $\frac{1}{6}$ inch range of motion downwards from the normal position (as figured). The actual motion of focussing displaces the optic axis slightly, as with the system adopted by Seibert and Krafft (figured and described *ante*, iii. (1880), p. 1047). But this displacement is of no practical moment, except where the Microscope is provided with a rotating stage, or where certain delicate micrometrical measurements are required. This focussing must be regarded as practically free

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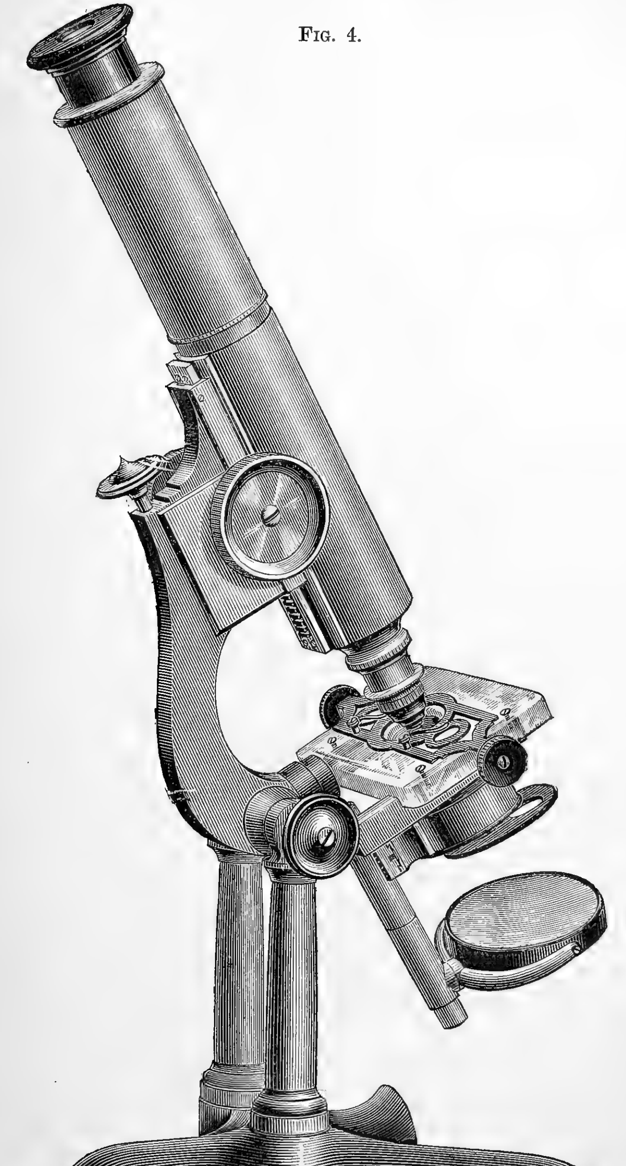
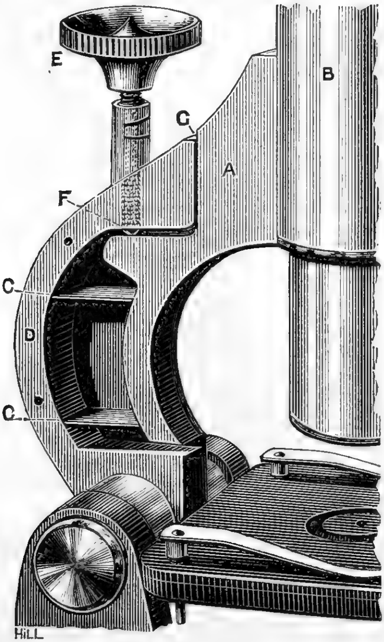
[*] See this Journal, iii. (1880) p. 1055.

Fig. 4.



from friction, as there are no metal surfaces in contact; the only friction is between the point of the screw at F, where it acts on the bar by pressure. The suspension of the optical body is strictly on the two springs C C. The open space shown at G is free from all contact of the metal faces. The metal plates used on both sides to cover up the mechanism in the limb (removed from the side in our figure to enable the construction to be seen) do not touch the moving surfaces.

Fig. 5.



It may also be noted as a novelty that the axis and foot of the Microscope are marked so as to indicate the proper degree of inclination required to place the camera lucida 10 inches above the table.

(2) *Investigator.* The general form of this instrument sufficiently appears from Fig. 6. The main tube has two draw-tubes, which is claimed to be an "entirely new feature in Microscopes, and an unquestionable improvement. It permits the use of the standard length of tube for quick adjustment in outside tube, the same as in instruments without rack and pinion adjustment; it serves also for any low-power objective, and the amplifier can be used in either combination. The outside tube has a broad-gauge screw, and an adapter with the

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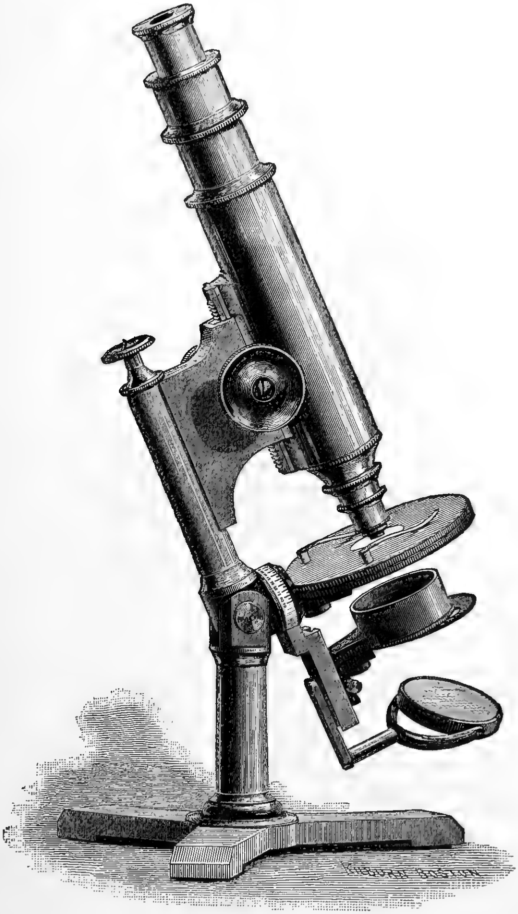
* The double draw-tube was adopted in a "revolving"-body Microscope constructed by Mr. Browning in 1873; it was figured in the Month. Micr. Journ., x. (1873) p. 234.

Society screw. The stage lies in the same plane as the centre of movement for mirror; it is of brass, and has concentric revolving motion. The mirror-bar swings upon one bearing, to any obliquity below and above the stage for the illumination of opaque objects, and has attached to it a secondary bar, to which the mirror is fitted, and which allows the separate use of the latter in any position of the substage. It is provided with a sliding arrangement, whereby the mirror may be moved to and from the object. The substage is adjustable along the mirror-bar, and entirely removable. It contains a diaphragm which may be brought directly under the stage. The ring is of standard size, and is centered by a set-screw."

Fig. 6.



Crouch's Histological Microscope. — Fig. 7 shows an inexpensive student's stand, as supplied by Mr. Crouch. The foot is of one casting. The stage has a glass bed. A substage slides beneath into a cylindrical fitting, with centering arrangement, as in Hartnack's stand; and sliding cylindrical diaphragms can be pushed up so as to be flush with the upper surface of the stage. The optical body slides

Fig. 7.

in the cloth-lined socket for the coarse adjustment, or rack and pinion can be provided.

The fine adjustment is shown above (Fig. 5).

Sidle's New "Acme" Microscope.*—Messrs. John W. Sidle and Co., of Lancaster, Pa., U.S., the manufacturers of the small "Acme" stand described and figured at pp. 522–3 of vol. iii. (the result of the combined suggestions of Professor J. E. Smith and Mr. Sidle), have perfected a larger stand substantially on the same model.

The binocular prism is contained in a sliding box, in a nose-piece that fits in the lower end of the body-tube by a bayonet-joint. By removing the nose-piece a clear field is given to lenses having the 1¼-inch screw, and by screwing into this thread an ordinary adapter with "Society" screw one is prepared for the use of low-power lenses of large apertures. This is an improvement, as most of the binocular stands do not permit of the employment of wide-angled objectives to their best advantage, in consequence of the diaphragms usually applied in the main tube.

The substage swings on a circle of 3¾ inches diameter, and is graduated to degrees. It moves along the swinging-bar by rack and pinion. The substage may be centered in the optic axis by two milled heads. This centering arrangement is of new construction, and is contained in the space between the substage ring and the slide, thus doing away with the large ring and set-screws found on some substages.

Tolles-Blackham Microscope.—We gave, in vol. iii. (1880) p. 520, a brief description of this stand, illustrated by a figure. Since that date an improved form has been constructed for Mr. Crisp, which he exhibited at the Society's November meeting, and which we here describe. The figure noted above should be referred to together with those now given.

Mr. Tolles has changed the shape of the foot; it is now in the form of an equilateral triangle, with concave sides and truncated angles, having pads of cork under each end. On the centre of the base a circular plate is turned, and on this rotates a second plate, carrying the pillars of the Microscope; the upper plate is graduated for measuring angles, and can be firmly clamped at any point.

At the back of the vertical disk, a "radial arm," to carry a mirror or other accessory is fitted to rotate laterally concentric with the object.

An extra large milled head slips on the upper part of the pinion of the fine focussing screw, which is intended primarily for use in focussing for micro-photography; for this purpose it is grooved round the edge, so that a thread may be wound on it and the focussing controlled some distance off. For ordinary high-power work, this large milled head adds to the sensitiveness of the focussing; it has been thus applied by Mr. Tolles for many years past.

The draw-tube is nickel-plated, and is said not to become sullied so readily by handling as the usual brass tube. It is graduated, and

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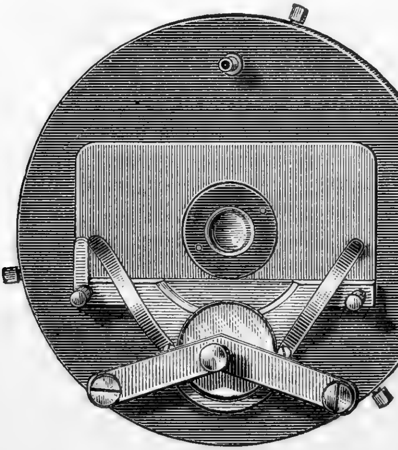
* Amer. Mon. Micr. Journ., i. (1880) pp. 203–4.

has the "Society" screw at the lower end for use with low powers. Mr. Tolles also applies the extra optical combination required for an erecting eye-piece in this position, and also his various forms of amplifiers—simple and compound.

The substage has a slight lateral swivel motion that enables the observer to direct the condenser very exactly radially upon the object, or to use various portions of the minute condensed cone of light, and it also compensates for the varying thickness of the object-slides by which the lateral circular track of the condenser may be rendered not quite concentric with the object. (We are informed by Mr. Tolles that to the earliest forms of his traversing substage-bar he provided special means to secure the exact radial direction of the illuminating pencil concentric with the object with different thicknesses of object-slide; he has forwarded a photograph of a Microscope thus constructed by him in 1873.)

Two stages are supplied that are interchangeable by a simple spring latchet arrangement, clipping them on the same fixed centering ring attached at right angles to the vertical disk. The one stage (*in situ* in the figure above referred to) is shown in Fig. 8, half size.

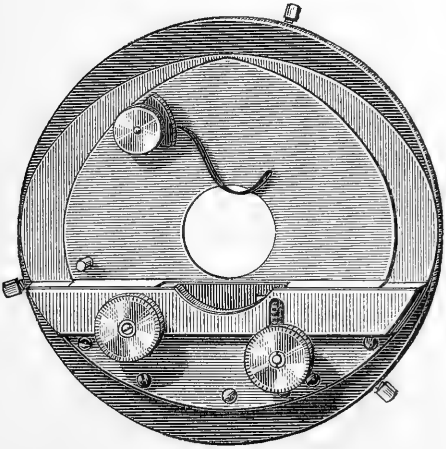
FIG. 8.



It rotates completely. The rectangular plate of German silver is about $\frac{1}{50}$ inch in thickness, and is attached to a glass friction-plate, held against the circular stage by an adjustable spring pressure-point; the thickness of this metal plate forms no hindrance to the use of the hemispherical lens, seen in the centre, which is intended to be used in immersion contact with the base of the object-slide.

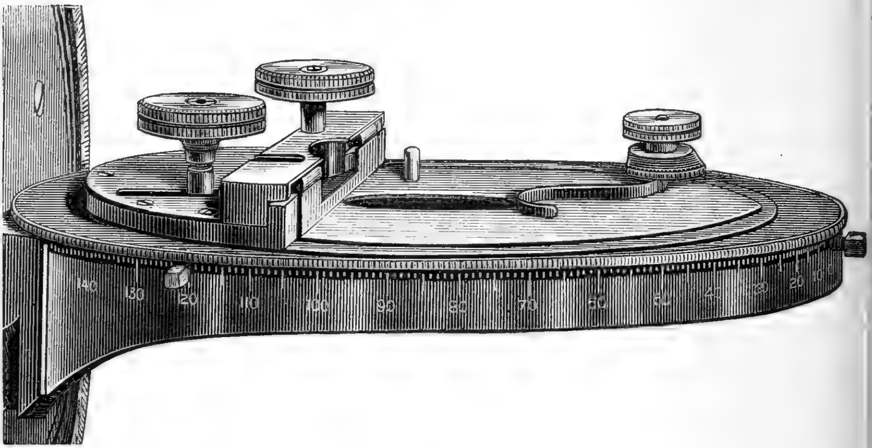
The mechanical stage (Fig. 9) presents several points of novelty. The rectangular motions are controlled on the *surface* of the stage entirely within the circumference. The milled head on the right is attached by a pinion to the circular base-plate (milled on the edge) and carries a toothed wheel that moves both plates in the vertical by a side-rack shown in the slot opening; whilst the other one acts on a rack, under the bar in the hollow horizontal track that forms part of the upper plate, and causes this plate only to traverse. The two moving plates are of German silver, each about $\frac{1}{50}$ inch in thickness; the lower one is held on the circular stage by three short pins with spring washers that travel in corresponding slots cut through the stage and forming a triangular support; the upper one lies nearly flat on the lower one, touching merely round the outer edge. The total thickness of this mechanical stage may be better appreciated by a glance at Fig. 10 (*actual size*), in which the ring, graduated on the edge, is the main stage ring, attached at right angles to the vertical disk (shown in part) having within it another one that carries either of the two moving stages figured, and which can be exactly centered to rotate on the optic axis by the three steel screw studs (two of which are seen on the edge). From the upper surface of the moving plates, where the object is placed, the perpendicular thickness is slightly less than half an inch—probably the thinnest mechanical stage ever made to a first-class stand. As no portions of the stage project beyond the circular edge in any position of motion, the complete rotation can be made. The absence of projecting pinions or milled heads is of some advantage in connection with the full radial swing of the substage.

Fig. 9.



When the Microscope is placed horizontal, the object on the stage is in a perpendicular axis, passing through the centre of the rotating foot; if then a lamp flame be adjusted in a line with the optic axis the rotation of the Microscope on the foot will provide a practically perfect range of oblique illumination on either side. The hemispherical lens, as applied to this stand by Mr. Tolles for immersion illumination, adds greatly to the facility of obtaining effects of obliquity; indeed, he appears to have been the first to distinctly realize the advantages of this kind of illumination, dating back from his first production of immersion objectives, having "balsam angle" greater than 82°.

Fig. 10.



Reflection from the Inside of Body-tubes.*—In their new form of stand, Messrs. Sidle prevent the formation of a burnished reflecting surface, produced by friction below the eye-piece, by turning an annular groove on the inner surface of the draw-tube, near the top, of such a width that the surface which is exposed to the friction of the eye-piece will not be uncovered, no matter what eye-piece may be used.

This device might (Mr. A. L. Woodward considers) be applied to any stand, at comparatively slight expense, whereas the application of a collar would necessitate either a new and larger body-tube or else a narrower eye-piece.

Whilst on the subject of making this improvement in connection with the eye-piece fitting, we would urge the importance of applying to the various eye-pieces such adapters as will bring the field-lens in each case to the same position in the tube. By this means (as adopted many years ago by Powell and Lealand) the estimation of the magnifying power is facilitated, and much of the inconvenience avoided of refocussing and readjusting when different eye-pieces are used with high-power objectives.

Adaptation of the "Society" Screw to Draw-tubes.—We observe in the various descriptive catalogues of American Microscopes, that

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* Amer. Journ. Micr., v. (1880) p. 185.

the draw-tubes of all sizes of stands are beginning to be fitted with the "Society" screw, to carry objectives at the lower end. This is a practical innovation, which might be generally adopted, we think, with advantage. The object is to enable low powers—such as 3 inch, 4 inch, or even 5 inch—to be readily used, the draw-tube providing convenient and rapid means of focussing roughly, without the body-tube itself having to be moved higher than the normal position, where the Microscope is well balanced.

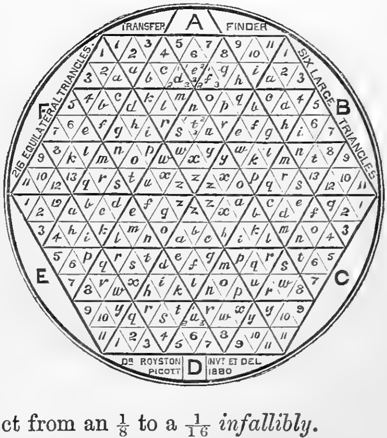
Accurate focussing can be obtained with large stands, by the usual coarse rack and pinion motion. The nose-piece of the main optical body (into which the higher powers are screwed) is not found to present any obstacle to the use of the draw-tube.

There is the further advantage in a screw on the draw-tube, that an objective can be applied to produce with the ordinary eye-piece an erecting arrangement, so that a special "erector" may be dispensed with. This, as is well known, enables wide variations in magnifying power with the same objective to be obtained, and is not only serviceable for dissections, but for the examination of gems, large specimens, and low-power work generally. Amplifiers may also be attached to the lower end of the draw-tube.

Dr. Royston-Pigott's General and Transfer Finder.—The following description is supplied by Dr. Royston-Pigott:—The finder (Fig. 11) consists primarily of six large triangles lettered A, B, C, D, E, and F at the margin. Each triangle is divided into thirty-six small triangles lettered or figured. Any triangle is identified by two letters, such as B*z*, E*x*, or F*r*. A platinum disk perforated with a small hole is made to slide or fold over into the position for zero. This is used only for finding objects generally. The triangulated finder is transparent, and is placed so as to occupy the stop in an A eye-piece.

Transfer Finder.—Plan.—The finder should just fill the stop of an A eye-piece, which must have a stud to correspond with the notch on the draw-tube, so as to keep the finder vertical in one position, and the notch should go through the eye-tube and draw-tube together.

FIG. 11.



Use.—To transfer say an object from an $\frac{1}{8}$ to a $\frac{1}{16}$ *infallibly.*

1. Use a standard inch always to mark the proposed $\frac{1}{8}$ or $\frac{1}{16}$ or $\frac{1}{32}$. Place a sharp object *in the centre* by the $\frac{1}{8}$ inch and finder. Then substitute an *inch* objective, and mark the position, say B*z*, on the finder. Upon placing any other object on B*z* with the inch, the given $\frac{1}{8}$ will show it in the middle of the glass.

2. Suppose it is required to find the triangle for a $\frac{1}{16}$. Take

any object in the centre with the $\frac{1}{16}$ and finder, then replace the inch objective, read the finder, say E*x* triangle, then on placing any other object with the inch objective on E*x*, on putting on the $\frac{1}{16}$ it will appear in the middle of the field.

3. Again, if an object be seen in the finder on B*z* with the inch, the object must be transferred to E*x* to transfer it from the $\frac{1}{8}$ to the $\frac{1}{16}$, and so on for a $\frac{1}{32}$. Say the inch finds it on F*r* when it was central in $\frac{1}{32}$. Then if any other object be placed on F*r* by the inch, it will be seen central by $\frac{1}{32}$, and E*x* for $\frac{1}{16}$ will be F*r* for $\frac{1}{32}$.

Use as a General Finder.—If the clip on the stage slides down and closes up so as to occupy the place where the object would be, a small piece of platinum wire is to be let in and riveted; then a small hole as fine as a watchmaker's pivot is to be drilled or punched through it. The position of this punctum should be a *mean* position, so as to correspond with the centre of stage motion. If this cannot be done, a small piece of brass is to fold over instead, carrying the platinum hole.

To use the Transfer Eye-piece.—Place an object with the inch on the centre of field; note the triangle where the hole is seen on being folded over into the field of view, say it is (A*t*). Then when the hole is again placed at A*t* the object will be in the centre of field, and if it be put on B*z* $\frac{1}{8}$ will find it, and if it be put on E*x* $\frac{1}{16}$ will find it, and if it be put on F*r* the $\frac{1}{32}$ will find it.

Angular Aperture—a Correction.—In a recent number of the 'American Journal of Microscopy,' Mr. Bragdon alluded to a $\frac{1}{10}$ oil-immersion, by Tolles, stating its aperture to be 148° in a medium of index 1·525, which would very nearly = 1·5 "numerical." Mr. Bragdon has since informed us that "148°" was a misprint for "141°," so that the $\frac{1}{10}$ in question has a numerical aperture of about 1·43.

Low Powers of Large Aperture.—We learn that Mr. Tolles, of Boston, has recently completed a $\frac{2}{3}$ objective of 0·58 numerical aperture (= 70° "angular" aperture), and that even with this large aperture the field is fairly "flat." It is said to resolve *P. angulatum* with oblique light *direct* from the lamp (that is, without any form of condenser); whilst, with a concave mirror used in the axis, it exhibits the lines on ordinary specimens, giving resolution in all parts of the field.

Notwithstanding its aperture, it has been constructed for use on the usual Microscopes having the "Society" screw. We believe that all previous attempts made in America to secure so large an aperture with this focus have required a larger gauge of screw, so as to permit the utilization of a back lens larger than the gauge of the "Society" screw.

Gundlach's Homogeneous-immersion Objectives. — Mr. Ernst Gundlach has recently forwarded to Mr. Curties a new $\frac{1}{8}$, constructed on a formula by which he states he will be able to secure longer working distance and an angle of aperture approximating to 180° in a medium of index 1·52 (that is to say, a numerical aperture approaching 1·52). He claims for the $\frac{1}{8}$ an angle of 140° (= 1·43 "numerical" nearly).

Secure Method of Setting the Front Lens of Oil-immersion Objectives.—Mr. J. Mayall, junr., sends us the following note communicated to him by Mr. Wenham:—

"The method usually employed to set the minute fronts of oil-immersion lenses, has been to 'burnish them in,' that is, to fit them exactly into the cell, leaving a thin rim of metal projecting round the lens, and while the setting is running in the lathe laying this over the edge of the glass, which should be slightly chamfered. With large eye-piece lenses this is an easy and certain operation, but with lenses less than one-eighth of an inch in diameter, it is one of the most difficult and delicate operations in optical manipulation. Not only is there some risk of fracture, but if at the time that the metal grips the glass, the surface should get out of truth from the tilting of the lens, this cannot afterwards be forced to run true, as the pressure required would certainly cause fracture; the only remedy is to cut out the lens and try again. I have seen a great number of minute lenses, that have been 'burnished in,' running out of truth simply because there is no absolute control over the operation; and to make an oil-tight fit, the brass, or other metal equally hard, must bear heavily on to the fragile glass, with the liability of distorting its figure.

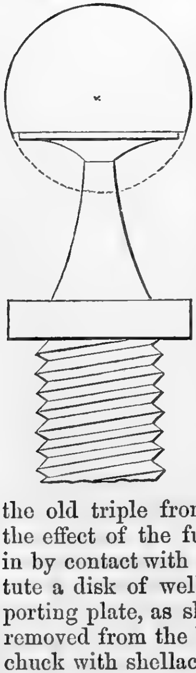
"Many years ago I set some minute eye-piece lenses in the following manner:—I turned the cell clear out, so that the lens would drop easily through. I then heated the cell, and with a conical-pointed copper wire, well tinned, and a fragment of rosin for a flux, I twisted the wire round till a ring of tin was well fused round the hole. I then turned the tin lining out true, to form the cell and bed for the lens, leaving the projecting ridge necessary for burnishing. This operation was performed with an ivory stylet lubricated with moist soap. Before the finishing touch is completed, if the face of the lens is seen to run out of truth (ascertained by the usual 'candle' test), the soft metal will yield to a moderate pressure applied on the proper side; the burnishing may then be completed without fear of the lens wabbling, and, finally, the edges neatly finished with a turning tool. I have set the front lenses of objectives this way, and the soft tin plies so well round the glass that no leakage occurs with any kind of oil or spirit; and lenses thus mounted may be pushed out from the back of the cell, for alteration or repair, without risk of fracture, as the portion of tin that has been laid over is raised up again without the application of a dangerous degree of force.

"The volatile oils or spirits used for immersion lenses, act energetically in softening or dissolving either Canada balsam or shellac, and it will not answer to employ these substances for rendering them oil-tight.

"For the purpose of making a leaky joint tight, I have found ordinary sulphur answer perfectly, as it is not acted upon by any cold immersion fluids that can be used, and as its melting point is about 220° Fahr., the heat required in its employment will not injure the coat of lacquer on brasswork. In order to cement a front lens oil-tight in its cell, it is sufficient to place this, with lens fitted in position, on to a hot plate, and drop a fragment of sulphur on the lens, raise the heat till the sulphur melts and flows round the edge. By capillary attraction it runs into the joint. Although the melted sulphur is very fluid, yet it has a singular disinclination to attach itself, or spread on a polished surface of glass; and this property quite prevents it from creeping over the back of the lens, as balsam or shellac will do, and when cold the button of sulphur on the front may be easily picked off with a needle point, leaving the surface of the glass clean.

"Fronts extending beyond the hemisphere have been proposed by Professor Stokes. I do not at present pretend to give a comparison of any degree of advantage or superiority over the common hemispherical front, as I have not yet tested the relative performances of both, as applied to the same object-glass. I have first to state that there is no great difficulty in constructing such lenses. In fact, from the mode that they can be worked in the mould, the figure of this form of lens is more likely to be perfect than a hemisphere. Having ascertained the thickness to be given from the flat face to the top of the sphere, a piece of glass polished on one side is flattened down to the thickness, then cemented on to a suitable chuck, on which the finished lens will appear, as in Fig. 12. In working and polishing, the sphere may be rolled round in the tool till the holding chuck and handle is carried out at right angles to the axis of the mandril of the lathe. We cannot go to this extent with a hemispherical lens without working off the edge too much, but the more a *sphere* is turned about in every direction, the more perfect the figure becomes.

FIG. 12.



"The difficulty has hitherto been to mount these balloon lenses securely. The plan that has been adopted is to set them on a plate of thin cover-glass, with Canada balsam or other cement, and burnish the plate in at the edge. The whole arrangement is thus so fragile that, after the balsam is hard and brittle, the mere act of wiping the front will probably start the surfaces, and the least pressure on the object-slide (which even the most careful manipulator cannot always avoid) will dislodge the lens, besides the objection of somewhat impairing the finest definition by two additional surfaces, even when cemented. I have seen a great number of instances wherein the old triple fronts made by Ross, as in Fig. 13, in order to gain the effect of the full hemisphere, have had the thin flint disk broken in by contact with the slide. In mounting the balloon front, I substitute a disk of well hammer-hardened metal, in lieu of the glass-supporting plate, as shown by Fig. 14. After the lens is polished, it is removed from the holder and its convex side cemented on to a ring-chuck with shellac, and the flat surface set true by the 'candle-flame' test. This can be quickly and easily done by warming the chuck with a spirit lamp. A groove is then turned round the corner of the lens, as shown, by means of a keen splinter of diamond, and the supporting plate turned to fit the groove, which plate is afterwards cemented or burnished in the front of the setting. To avoid risk of pushing the lens in by pressure, the face should not be quite flush with the front of the plate.

FIG. 13.

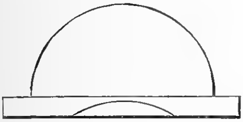
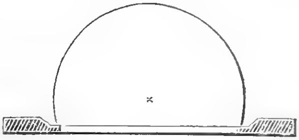


FIG. 14.



"To cement the lens into the plate, lay this on a piece of tissue paper set on the hot plate, put a fragment of sulphur into the ring, and the lens on the top of this. When the sulphur has melted, press the lens well down into the ring. After the whole has cooled, the surplus sulphur comes off by a pull with the paper. In turning out the groove at the corner of the balloon lens, there is but little risk of splintering the glass, if a suitable diamond point is used. The small fracture in the lens shown, was occasioned by the use of a ring emery grinder, rather too small, intended to take off the rough cut of the diamond; but I consider this after smoothing operation unnecessary, as it is more hazardous to use than the diamond itself.

"I have found the best way of mounting these diamond splinters to be thus: Take a short piece of copper wire, and split the end down about one-eighth of an inch with a watch-spring saw; open out the split and anneal the end by heating it red hot. Lay the splinter of diamond on one of the open sides, sticking it on with a touch of Canada balsam. When the point appears fairly projecting in the direction required, close the split together with pliers, well pinching it on to the diamond; this becomes imbedded in the soft copper. Finally, by means of the blow-pipe and borax, run silver solder into the slit, and thus the diamond will be very securely fixed."

New Homogeneous-immersion Fluid of 1·5 Refractive Index.—Mr. Charles H. Bassett, of Boston, U.S.A., has recently communicated through Mr. Tolles a formula for a new immersion-fluid, which has proved successful with Mr. Tolles's high-angled homogeneous-immersion objectives. We quote from Mr. Bassett's instructions:—

"The formula for the new 'homogeneous-immersion fluid' of refractive index 1·5 is:—

Schering's chloral hydrate, in crusts	grs. 485
Bower's pure glycerine	grs. 70

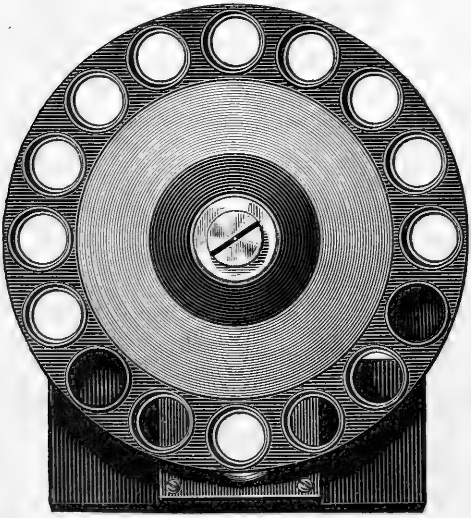
Mix, and dissolve in an open-mouthed bottle by means of a water bath.

"No special manipulative skill is required in the preparation of this fluid; due care, however, should be exercised in *weighing* the ingredients, also in seeing that the chloral is of Schering's manufacture, and in *crusts* instead of crystals; the glycerine should also be *pure.* Place the articles in a thin open-mouthed bottle, which should be partially immersed in cold water contained in an ordinary saucepan. Heat the water to the boiling-point, and continue the boiling until the chloral is dissolved, which will occur in ten or twelve minutes. When cold the mixture is ready for use. It can be readily removed from the objective and slide with cold water, or if in haste, equal parts of methylated alcohol and water will act more promptly."

We understand that Mr. Bassett has for some time applied his practical knowledge as a chemist to the problem of discovering a suitable fluid for homogeneous immersion. He places the above result of his labours before the Society in the belief that it will be found of good service.

Bausch and Lomb Optical Company's Slide-holder.—This (see Fig. 4) is a substitute for a mechanical stage. It consists of a German-silver plate of very light weight, moving on a strong glass plate which forms the immovable stage. Only four small points of the metal plate touch the top of this glass plate, while two prolongations of the former, bent downward and backward and acting as springs, press against the under side of the glass plate with just sufficient force to keep the slide-holder in position and to prevent it from slipping off when the Microscope is inclined. Two small knobs facilitate the handling of the slide-holder. It is claimed that the arrangement exceeds in smoothness and evenness of motion the ordinary form of movable glass stages, and at the same time, while the movable part is of less weight, the glass plate can be of sufficient strength to guard against easy breaking. The glass stage has later been made circular (and thinner), and the slide carrier revolves.

FIG. 15.



Beck's Rotating Holder for Rubber Cells.—Fig. 15 (half size) shows this holder (referred to at p. 1041, vol. iii.), which forms an addition to the list of microscopical appliances in which ebonite is used.*

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* See this Journal, iii. (1880) p. 1082.

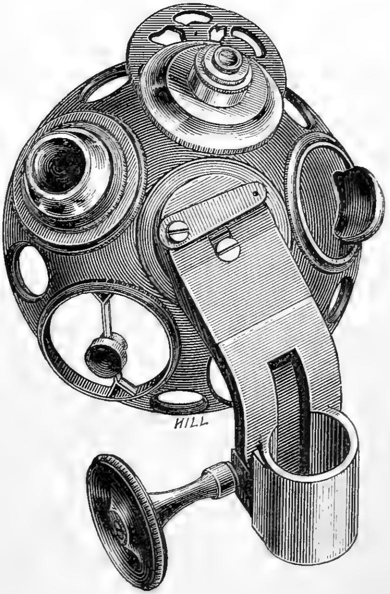
The rectangular plate (at the lower part of figure) is attached to the stage of the Microscope by the usual spring clip, and is adjusted so that a cell is in the field of view. The upper, circular, tablet—in the openings of which the cells are placed—can then be rotated, and the contents of the whole sixteen cells passed in review.

For public exhibition, at soirées, &c., this rotating holder will be found very convenient. It is very light, and not easily injured.

Wallis's Calotte Substage.—At the December meeting, Mr. G. Wallis exhibited a Microscope of his own design and construction, the chief novelty of which was the substage, shown in Fig. 16.

The substage is formed of a strong brass calotte, upon which Mr. Wallis applies (1) a silver side reflector (shown on the right of the figure), (2) an achromatic condenser with its system of diaphragms, (3) a paraboloid, (4) a dark well, (5) a clear opening for use without special apparatus. On the inside of this calotte a section of another one is mounted to rotate on the same centre, and carries selenites and ground and tinted glasses, and similarly a third carries the polarizer; so that either or both can be rotated and used beneath the achromatic condenser. The whole is mounted on a pinion at an angle of 45° on a substage arm (moved by rack and pinion), so that the rotation of the outer calotte figured will bring each piece of apparatus into the axis of the Microscope, where a spring stop holds it. A fixed washer between the plates prevents the motion of the one being communicated to the others, each acting independently.

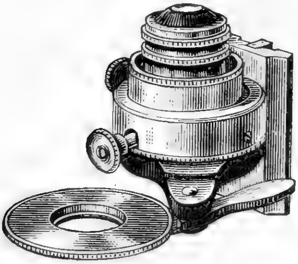
FIG. 16.



Mr. Wallis claims that in this manner all the substage apparatus usually adapted to the Microscope can be carried ready for immediate service, thus dispensing with the trouble of applying each separate accessory whenever required. He uses a similar calotte nose-piece carrying sundry objectives, and states that he leaves all his apparatus thus attached to the Microscope in constant readiness for any investigation he may desire to make.

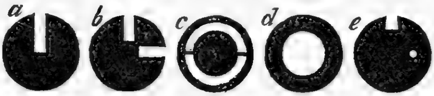
Centering Nose-piece as a Substage.—Mr. E. M. Nelson has suggested that for use on small Microscopes, the ordinary centering nose-piece can be easily applied as a substage (see Fig. 17), thus providing convenient centering motions with which small instruments are not usually supplied by opticians. The optical part of a $\frac{4}{10}$ objective then forms an excellent condenser; for this purpose it should be fitted with the shortest possible adapter, so that diaphragms may be used close beneath the back lens.

FIG. 17.



Mr. Nelson has also suggested the application of diaphragms beneath such a condenser in an annular disk-fitting swinging sideways on a pivot, the disk having a ledge within, on which one, two, or three diaphragms of various shapes may be placed together, and rotated by a milled edge (shown in the figure projecting beneath with shaped handle serving to move the disk out of the axis to change the diaphragms). The practical management of the diaphragms is obviously of the first importance in obtaining variety of effects of light with a condenser in the axis. Mr. Nelson has found the most useful series of diaphragms to be those represented in Fig. 18, in which *a* may be regarded as a type shape for one pencil of light, and *b* for two—at right angles. The superposition of stops like *c* will cut off more or less of the central light, while *d* will cut off more or less of the peripheral zone; *e* is a combination in which the square opening is intended to utilize the most oblique pencil required for the resolution of very fine lines, &c., whilst the small circular aperture is calculated to give a beam of light for the resolution of less difficult markings on the same object at right angles—for instance, on *Surirella gemma*. It is advisable to have a variety of sizes of *c* and *d*, as upon these depend most of the difficult resolution to be obtained by using the condenser in the axis.

FIG. 18.

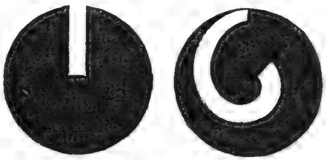


Of course the above arrangement for diaphragms can be applied to any form of condenser, and is not confined to the centering nosepiece.

Mayall's Spiral Diaphragm for Oblique Illumination.—At the Society's December meeting, Mr. J. Mayall, jun., described a spiral diaphragm, which he had devised as a convenient means of obtaining oblique illumination in connection with high-angled condensers to be used in the axis of the Microscope.

If a slot diaphragm (as shown in Fig. 19) be fixed close beneath the large lens of a high-angled condenser, such as those lately constructed by Powell and Lealand, and by Zeiss, the rotation under it of a diaphragm having a spiral opening (as figured) will provide a pencil of light at *varying* degrees of obliquity throughout the range of aperture of the condenser. The azimuthal direction of the incident pencil will of course be controlled either by rotating the *object* or the *condenser* carrying the diaphragms; whilst the rotation of the spiral on the fixed slot will not change the direction in azimuth, but only in altitude, so far as the aperture of the condenser will permit.

FIG. 19.



The diaphragms hitherto applied for this purpose have for the most part had but a very limited range of action in *varying* the angle of oblique incidence of the illuminating pencil; indeed, with the exception of Professor Abbe's traversing diaphragm plate fitted to his recent forms of substage condensers, we are not aware that any efficient means for this purpose has been devised. Professor Abbe's plan requires a special horizontal rack and pinion made to the substage to allow the free motion of the diaphragm.

High Amplifications.—References have been made by a lady correspondent in recent numbers of the 'American Journal of Microscopy,' to an amplification of upwards of 20,000 diameters obtained with a $\frac{1}{6}$ objective using an eye-piece of $\frac{1}{50}$ equivalent focus. On the usual assumption that a 1-inch objective gives a magnification of 10 linear, a $\frac{1}{6}$ would give 50, and a $\frac{1}{50}$ eye-piece 500: the combined amplification would therefore be $60 \times 500 = 30{,}000$ linear. A few instances of practical results obtained with high amplifications cannot but make us feel sceptical of the value of the definition obtained with a $\frac{1}{50}$ eye-piece.

Sir John Herschel, in his 'Treatise on Light,'[*] mentions having "viewed an object *without utter indistinctness* through a Microscope by Amici, magnifying upwards of 3000 times in linear measure."

In the very early days of the collodion process in photography, Mr. Wenham exhibited a micro-photograph of *P. angulatum* magnified 15,000 linear: it is no disparagement to the photograph (a copy of which we have recently inspected), to say that it is not remarkable for distinctness. It was produced with the first compound achromatic $\frac{1}{25}$ ever made in this country; and the lens coming from the hands of an amateur optician, and the photograph being produced by the same amateur photographer, the result was then regarded as an almost marvellous specimen of practical skill and ingenuity.

Some thirteen or fourteen years ago, Hartnack had a micro-photographic transparency on ground glass of *P. angulatum* exhibited in his *atelier* in the Place Dauphine, Paris. The magnification was about 3000 linear; the image was well defined to the edges—about 16 inches square—and was produced with one of his then best No. 10 immersions.

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[*] Encyc. Metrop., p. 581.

In 1867, Dr. Woodward, of Washington, forwarded to Dr. Maddox for exhibition to the Society, a series of micro-photographs of *Podura* scales, and various other test objects produced with sundry objectives, notably Powell and Lealand's $\frac{1}{50}$, $\frac{1}{25}$, and $\frac{1}{16}$ dry lenses. The amplifications did not exceed 2100 linear. Dr. Maddox then remarked that he believed "the *Podura* scale had never yet, in this country, been photographed by a $\frac{1}{50}$." The *Navicula rhomboides*, by Wales's $\frac{1}{8}$ and amplifier, magnified 800 linear, was especially admired.* Shortly afterwards, Dr. Woodward presented to the Society a large series of micro-photographs of Nobert's 19-group test-plate, and other test objects—the direct amplifications not exceeding 2000 linear.

At various dates micro-photographs have also been brought before the notice of the Society by Dr. Maddox, Dr. Woodward, Count Castracane, Mr. S. Wells (of Boston), and others, and the direct amplifications have rarely exceeded 2000 linear.

In 1868, Mr. Charles Stodder, of Boston, having access to a number of the presumably best objectives in America, was content to specify his own magnifications as not exceeding 1062 linear (though he referred to 6000 obtained by Messrs. Sullivant and Wormly),† and he particularly commended the performance of Tolles's $\frac{1}{6}$ immersion, as "the best on record"—and yet the magnification was only 550 linear for the resolution of Nobert's 19th group.‡

It is to be supposed that experienced microscopists like these have in every case sought to do full justice to the objectives in their hands, and it may be noted particularly that with so difficult an object as the highest group on Nobert's 19-group plate, Dr. Woodward, down to the latest date on record, has limited his micro-photographic operations to *less* than 2000 linear of *direct* amplification. His more recent series of micro-photographs comprised *A. pellucida*, both dry and in balsam, the magnifications hardly exceeding 3000 linear, though the objectives included $\frac{1}{25}$, $\frac{1}{16}$, and $\frac{1}{8}$ immersions of Powell and Lealand, $\frac{1}{25}$ and $\frac{1}{18}$ immersions, and $\frac{1}{10}$ oil-immersion of Tolles, $\frac{1}{10}$ glycerine immersion of Spencer, $\frac{1}{8}$ and $\frac{1}{12}$ oil-immersion of Zeiss. The last objective named he regarded as the most powerful "resolving" lens he had seen up to the date of his communication (October 1879). Dr. Woodward has then been contented with about 3000 linear to exhibit the *best* definition of the objectives in the well-known official collection of the Army Medical Museum at Washington.

At p. 821, two micro-photographs of *P. angulatum*, by Günther, of Berlin, were referred to; they were produced with Gundlach's No. VII. immersion, the direct magnifications respectively 2000 and 5900 linear—obtained by receiving the images at conjugate distances of 1 metre and 3 metres (nearly). These excellent prints have since been received, together with one of *Frustulia saxonica* in balsam, magnified about 5000 linear (enlarged from the original photograph), showing an appearance of beaded structure even more palpably than

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* Quart. Journ. Micr. Sci., No. xxix. (1868). (Proc. R. Micr. Soc., p. 63.)

† Amer. Journ. Sci., Jan. 1861.

‡ See reprint of Mr. Stodder's paper on "Nobert's Test-plate," &c., Quart. Journ. Micr. Sci., No. xxxi. (1868) pp. 131–8.

in Mr. S. Wells's micro-photograph exhibited at the Society in 1876.*

If, among the above results, we select as a standard Dr. Woodward's micro-photographs of *A. pellucida*, produced with Zeiss's $\frac{1}{12}$ oil-immersion, we shall find that (apart from the use of an amplifier) the magnification was obtained by receiving the image at a conjugate distance equivalent to the use of an eye-piece magnifying 25 linear—that is to say, the $\frac{1}{12}$ would give 120, and this combined with an eye-piece of 25 would produce 3000. An eye-piece of 25 being of $\frac{2}{5}$ equivalent focus, it follows that the eye-piece ($\frac{1}{50}$) referred to by the lady correspondent is just 20 times as strong (500 as against 25) as that which Dr. Woodward thought most effective to exhibit the best resolving power of Zeiss's $\frac{1}{12}$.

Applying similar reasoning to Mr. Charles Stodder's example, i. e. Tolles's $\frac{1}{6}$ giving 550 linear, we learn that he obtained his "best result on record" with an eye-piece of about 9 linear, that is, less than 1 inch equivalent focus—a startling difference when compared with a $\frac{1}{50}$ with its 500 linear.

Mr. Dallinger referred to 10,000 or 15,000 diameters in his lecture at the Royal Institution and at Cambridge (1879), but when describing his results in his paper to this Society,† he pointedly stated that his *best* results were obtained with Powell and Lealand's new formula $\frac{1}{8}$ immersion, and his magnifications were less than 4000—that is to say, his eye-piece power did not exceed 50 linear.

Here, then, we have roughly collected a few instances of practical results, to which we draw special attention, as clearly indicating that in the opinion of some of the best living manipulators with the Microscope, amplifications beyond 5000 or 6000 linear exhibit no further visible resolving power; indeed we think these figures are far in excess of the practically useful limit, and that from 2000 to 3000 linear would amply represent the limit of visible resolving power.

In America, more than one professed microscopical expert—notably Mr. John Phin, editor of the 'American Journal of Microscopy,'‡ and "Carl Reddots," §—has lately alluded to 80,000 or 100,000 diameters as within the power of his appliances. With the evidence of micro-photographs before us, we must regard any such magnification as of no practical scientific value. We say this the more advisedly from the fact that we have tested some of the finest specimens of American optical work, including the choicest objectives from the hands of Tolles, Spencer, and Wales; we have also tested the best lenses we have met with of Powell and Lealand, Zeiss, Hartnack, Prazmowski, Nachet, Seibert and Krafft, Bénèche and others, and our conclusion is, that the use of any such eye-pieces as $\frac{1}{50}$ cannot be regarded as anything more than microscopical eccentricity, originating probably from that very common popular error of making the value of a Microscope to depend exclusively upon its magnifying power.

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* Mon. Micr. Journ., xvi. (1876) p. 169.

† Ibid., xiv. (1875) pp. 105–8.

‡ Eng. Mech., xxxi. (1880) p. 469.

§ Amer. Mon. Micr. Journ., i. (1880) p. 39.

Highest Magnifying Powers.*—Mr. A. Y. Moore also refers to the same subject under this title.

It is well known to all practical microscopists that the magnifying power of an objective may be increased by eye-piecing to a certain extent, with a continued gain in resolving power. When the limit of resolving power is reached the magnifying power may be further increased, but nothing is gained, except in the apparent size of details already shown. After this comes a period in which the magnifying power may be increased almost indefinitely; but it is now very noticeable that the resolving power is impaired. The aberrations of the objective interfere greatly with the image. In fact, it is here that a lens is frequently said to "break down."

These three stages may be conveniently studied in an ordinary cheap $\frac{1}{4}$ of 100°. With an amplification of 300 diameters such a lens should easily resolve *P. angulatum*, but try as best we can, the lines of *Surirella gemma* will fail to be seen. Now, if a higher eye-piece be applied, giving a power of 500 diameters, this diatom may be resolved. Supposing this to indicate the limit of resolvability of the object, a still higher eye-piece may be used; but the resolution is simply shown larger. This period probably will extend to 1000 diameters, but if increased much beyond this less is seen at each increase of power.

The extent to which these three stages may be carried is, of course, dependent upon the quality of the objective and its angular aperture. In testing objectives the magnifying power should be carried to the second stage, for a lens is frequently defeated simply because the visual angles subtended by the lines (or dots) are insufficient for recognition by the eye.

In a recent article in the 'American Journal of Microscopy' a magnifying power of 100,000 diameters is mentioned, obtained by means of a Wales' $\frac{1}{15}$. From the fact that *P. angulatum* was the extent of its resolving power, it is seen that the lens was far into the third stage of its magnifying power. Any such increase of power is, so far as practical work is concerned, useless; but the second stage is what we need and want. Frequently details are seen, but are so small as to tire the eyes; while if enlarged by a higher eye-piece fatigue is prevented.

Mr. Moore suggests the question, What is the highest power ever attained and used *without* losing resolving power, and what objectives are best suited to yield such powers? Will a $\frac{1}{25}$ or $\frac{1}{50}$, with lower eye-piecing, give better results than a $\frac{1}{6}$ or $\frac{1}{10}$ with high eye-pieces and the magnifying powers the same? He is only able from personal experience to give the result of using a $\frac{1}{50}$ eye-piece, with a $\frac{1}{6}$ objective of "180°" (or 100° "balsam angle"), giving a magnifying power of 32,500 diameters. With this he was able to see the last three diatoms of the balsam Möller Platte clearly resolved. The lines of No. 20 did not look exactly like "the pickets on a fence," but more like a lean horse's ribs. The eye-piece was not certainly *easy* to use, and sunlight was necessary to see anything at all.

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* Amer. Journ. Micr., v. (1880) pp. 174–5.

Origin of Homogeneous Immersion. — In describing a new diatom* (*Navicula synedriformis*), the Abbé Castracane mentioned that he had made use of a homogeneous-immersion objective of Zeiss, "the principle of the construction of which is due to the celebrated professor G. B. Amici, but the realization to Professor Abbe."

On this statement Professor Abbe writes to us as follows:—

"My sincere estimation of the prominent merits of Amici—whom I consider to be the very father of modern microscopical optics—need not prevent my pointing out that it is incorrect to ascribe the homogeneous-immersion method to him.

Amici, it is conceded, first applied *oil* immersion, but the use of oil, by itself, does not constitute *homogeneous* immersion.

Amici did not aim, and indeed at that time could not have aimed, at the specific advantage of an immersion fluid being *as near as possible*, in refractive and dispersive powers, to the crown glass. Some of his oil lenses require, for good correction, a liquid of considerably *less* and others a liquid of considerably *higher* refraction. From what is known of Amici's oil lenses it is clear that he availed himself of the different refractive powers of various oils and mixtures of oils for obtaining the best correction of his lenses *after he had finished them*, but did not direct his work to any definite refractive index of immersion fluid *prescribed previously*, except perhaps in favour of water immersion. This is so natural that it would be unintelligible if Amici had proceeded otherwise; he *could* not aim at the peculiar optical benefits attendant upon the index 1·50 in comparison with 1·45 or 1·55, because it would have been utterly impossible to utilize it practically at that period. This requires a refinement of technical art which was not attained by the manufacturers of immersion objectives until a much later time.

The essential fact, in the principle of homogeneous immersion, is the increase of optical performance obtained from the total suppression of spherical aberration in *front* of an objective, and it was Mr. J. W. Stephenson who, in his first communications with me, expressed the opinion that doing away with the anterior aberration would improve the defining power, and especially would afford *very favourable conditions for further increase of aperture*, and suggested that the matter should receive an exhaustive theoretical and practical investigation by Mr. Zeiss and myself.

This suggestion, which had not been previously made (though it is very self-evident *now*, as is always the case after a thing has been done), is the true origin of the homogeneous-immersion method, and the basis of the superior performance of objectives of this kind."

The Essence of Homogeneous Immersion.—In a subsequent note Professor Abbe gives the following further explanation of what is the essence of homogeneous immersion from the optical point of view:—

"The peculiar performance of the non-achromatic, approximately hemispherical, front lens which is always used for wide-angled systems (the invention of which by Amici is in my opinion the very

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* Accad. Pontif. de' Nuovi Lincei, xxxiii. Sess. II., 25 Gennaio, 1880.

basis of the progress of the Microscope in the last forty years), is characterized by the circumstance that by this form of construction the refractive action of the first *spherical* surface of a system may be obtained, either free from any spherical aberration, or with a very harmless kind of aberration, which admits of exact correction at the upper parts of the system. But there remains still a considerable aberration affecting the pencils before they reach the spherical surface on their passage from the radiant to the medium of the front lens. In the ordinary case of a crown front this aberration depends solely on the *thickness* of the layer of deviating refractive index (air, water, &c.), by which the pencils are admitted, and on the difference, defect or excess, of the refractive index of this layer from the refractive index of crown glass, i. e. on the working distance and on the prescribed working medium of the system. In high and even moderate powers working distance must always be a perceptible fraction of the focal length. When an objective works through air, and in less degree when it works through water or glycerine, the aberration in front bears a considerable proportion to the total spherical aberration occurring within the system, and in the case of a wide-angled lens it is by far the most obnoxious part, for these two reasons: because it affects the cone of rays where it has its maximum angular extension; and because every residual passes to the microscopical image with the total amplification of the objective.

Owing to the former circumstance the anterior aberration is subjected to a very disproportionate increase from the axis to the external parts of the cone as soon as we deal with wide apertures. Whilst in the case of small angles the spherical aberration may be expressed with sufficient approximation by a single term, varying with the square of the inclination to the axis, the anterior aberration of a wide-angled system is composed of many terms varying with the successive even powers of the angle, all of which up to the eighth and tenth power acquire considerable values in respect to the most oblique rays. An aberration effect, the components of which are so very disproportionate, cannot be exactly balanced by opposite (negative) aberration at the upper surfaces of the system where the pencils are contracted to much narrower angles, for these narrower pencils do not admit sufficiently large terms or components increasing by the eighth or tenth powers of the angle. The correction of the anterior aberration must therefore be effected by a rather coarse method, balancing the higher terms by an *excess* of lower terms of opposite aberration at the posterior lenses. This method, of course, cannot afford a *uniform* correction of the whole pencil from the axis to the marginal rays; there will always remain an uncorrected residuum which rapidly increases with increasing aperture, and which appears in the image amplified by the total system as has been indicated above.

This residuum of anterior aberration, which is incapable of correction, and the regular chromatic difference of spherical aberration, are the two principal difficulties attendant upon very large aperture angles. Any non-homogeneous working medium (air, water, &c.), being supposed, there is a maximum angular aperture which cannot be surpassed without undergoing a perceptible loss of definition provided a certain working distance is required.

Withdrawing now the front aberration by an immersion fluid which is equal to crown glass in refractive power, and withdrawing it *for all colours at the same time* by selecting a fluid similar to crown glass in dispersive power likewise, will at once remove the difficulty. Consider for example an aperture of 1·25 (numerical). Water being prescribed as immersion fluid, the front aberration would affect a pencil of 140°, containing rays up to an obliquity of 70°, and with strong glycerine of 1·45 this latter angle would remain 63° still. Substituting a medium which performs like fluid crown glass, the same pencil (contracted to the equivalent angle of 112°) will be admitted to the front lens without any aberration, and owing to the performance of the Amici type of construction, may be made to emerge from the curved surface of the front lens without any detrimental aberration, but contracted to an angular aperture of 70° to 90°. The first notable spherical aberration of the pencil then occurs at the anterior surface of the *second* lens, where the maximum obliquity of the rays is considerably diminished already.

A numerical aperture of say 1·25 represents a water angle = 140°, a glycerine angle of 126°, and a crown-glass angle of 112°. If, now, such an objective of 1·25 should be made for working with water (Fig. 20), there would be a cone of rays extending up to 70° on both sides of the axis, *and this large cone would be submitted to spherical aberration at the front surface a;* with glycerine this would be similar, though in less degree.

Fig. 20.

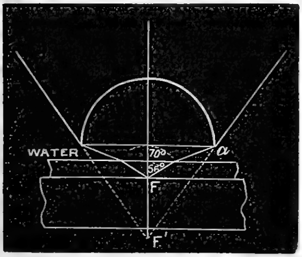
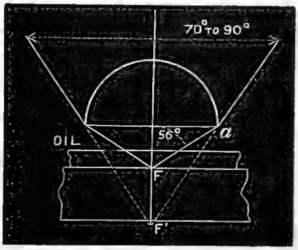


Fig. 21.



But if there is homogeneous immersion (Fig. 21), the whole cone of 112° angular aperture is admitted to the front lens without any aberration, because there is *no refraction* at the plane surface. And as the *spherical* surface of the front lens, though it may effect a considerable refraction, is without notable *spherical aberration*, the incident pencil likewise is brought from the focus F to the conjugate focus F′, and contracted to an angle of divergence of 70–90° without having undergone any spherical aberration at all.

Thus the problem of correcting a very wide-angled objective is reduced *by the homogeneous-immersion method, both in theory and in practice, to the problem of correcting an objective of moderate air angle.*

On this principle, by which the Amici type of construction is brought to its full efficiency, is based the optical advantage of the homogeneous-immersion method: i.e. the advance of defining power *per se* which is due to the exclusion of disproportionate aberration, and the increase of aperture which is *reconcilable* with perfect definition without needing any reduction of working distance apart from the requirements of technical work in high-power systems."

'The Northern Microscopist.' *—We are pleased to see the first number of a new Microscopical Journal under this title, edited by Mr. George E. Davis, a Fellow of the Society. It is hoped that its establishment "will be a bond of union between workers in the North, and that it will bring to the fore many men whose researches have scarcely been heard of, on account of their distance from the great microscopical centres;" and amongst its aims is the keeping of a record of the proceedings of the chief Microscopical Societies in the North, and so furnishing each individual member with at least as much permanent information as he would obtain if the Society to which he belonged published its own transactions—possibly more.

β. Collecting, Mounting, and Examining Objects.

Dr. Maddox's modified Aeroconiscope.—The modified form of Dr. Maddox's "Aeroconiscope," exhibited by him at the ordinary meeting of the Society on the 10th November, is figured in the accompanying woodcut.† It can be used as a vane, like the one employed in the experiments recorded in the 'Monthly Microscopical Journal' for 1870 (where the original form is figured), or with an aspirator, which can be driven by any means selected to draw a current of air through the instrument.

It consists essentially of an apparatus to collect the atmospheric dust, &c., and deliver it upon a slightly glutinous surface. In this case a glass tube *b*, and a funnel *a*, which supports a platinum wire bent as shown in the figure, to hold a thin microscope cover-glass, and at the opposite end to the funnel a pair of wings, attached to a split ring, which slides on *b*, the whole supported, as seen in Fig. 22, on a conically pointed steel pin. This pin can be screwed into a reversible clamping screw, to fix on the edge of a table, chair, or window-ledge, or slips into a socket on the side of the upper vessel of the aspirator, as at *d*. The glass tube of the vane, if used fixed, is attached by a short piece of indiarubber tubing, by which the air, after depositing the dust, escapes into the upper vessel previously filled with water, and allowed to empty itself into the lower vessel, thus creating a slight current through the apparatus. If used as a vane for the wind to blow through, of course it would be necessary to detach the indiarubber tubing, and allow the vane to gyrate upon the conical pin, fixed, if

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* 'The Northern Microscopist,' vol. i. No. 1. January. 24 pp. 1 plate and 2 figs. (8vo. London and Manchester, 1881.) 6*d*.

† See 'British Medical Journal,' Nov. 20, 1880.

preferred, on an ordinary triangle camera-stand. The funnel *a* should have a shorter stem than as figured, which was drawn to avoid confusion in the figure; and to still further simplify it and get rid of some of the weight, it can be made to fit the neck of the tube *b*, as a stopper fits a bottle. This is believed to be the preferable way, whether the funnel be of glass or sheet-metal, and in this case the platinum wire support *c*, can be fixed by a small adjustable clamping ring, to the tube which passes through the brass cap at the opposite end of *b*. The wings can also be made to fix on this cap, and thus still further reduce the weight by getting rid of the split ring, to which they were fastened in the form exhibited and here figured. The apparatus after removal of the wings drops into the closed chamber *f*, for convenience of carriage, and the upper vessel, of a known capacity, fits into the lower one, after removing the supports by which it is held in place when in use. The top vessel is filled through the stoppered neck, whilst the water is allowed to escape into the lower vessel through an aperture near to the bottom, which can be closed by a solid indiarubber plug, *vide* Fig. 22. These vessels may be made of any convenient size, or the lower vessel, or indeed both vessels, can be got rid of, and the vane, supported by the clamping-screw to a table, can be connected to a large jar full of water, placed on a chair, closed with a tight-fitting cork, through which two tubes pass, one to receive the end of the indiarubber tube, and the other the short leg of a flexible siphon, reaching inside to the bottom of the jar.

Fig. 22.

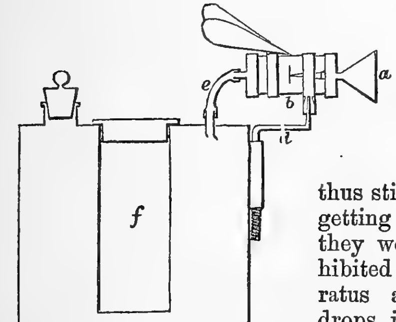
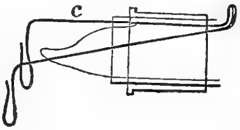


Fig. 23.



The great object has been to combine in one instrument the vane and aspirator forms, rendered as portable and of as little cost as possible. If to be set up definitely at any particular spot, the dimensions would necessarily be increased, and some form of aspirator used that would draw regularly a measured quantity of air through the apparatus in a given time, as twenty-four hours, more or less. This would increase the complexity and expense, though doubtless it would furnish more important data than the present portable form.

Glycerine or glucose, singly or united, can be used to smear the centre of the thin glass cover opposite the nozzle of the funnel, if intended for direct microscopical examination; but if for cultivating the entrapped germs, some other medium, containing animal matter in a sterilized solution, with a little acetate of potash, can be employed, and the cover placed on a cultivating slide or in a cultivating chamber; or, removing the thin cover-glass, the air can be drawn in direct into a sterilized medium interposed between the nozzle of the funnel and the aspirator.*

Herpell's Method of Preparing Fungi for the Herbarium.†—The editor of the 'Collection of Prepared Hymenomycetous Fungi,' publishes the method employed by him in his excellent preparations, commencing with some advice as to the collection of Hymenomycetes, with the special view of bringing home the fungi uninjured and in a condition for preparation.

The process itself is as follows:—Some finely cut gelatine is first dissolved in five parts of boiling water, and the solution daubed as thick as possible on some leaves of stiff writing-paper. One of these leaves of gelatinized paper is then moistened on the clean side and laid on a flat moistened plate. The sections of the fungi are then prepared, viz. a vertical section through the centre of the entire fungus, and superficial sections of the pileus and stipes, taken so as to cut away as much as possible of the flesh. These sections are laid on the gelatinized paper, and then pressed under a weight of 25 kilo. between white blotting-paper. After twenty-four or forty-eight hours they are regularly turned over for from two to four days; the sections are then dry, and can be cut out and fixed with gum.

The "spore-preparations" are obtained in the following way:—Immediately after the fungus is collected, the pileus is laid with its under side on paper; white writing-paper being used for all the Hymenomycetes with coloured spores; blue sized-paper for the Russulæ, Lactarii, and Cantharelli with white spores; blue English cardboard for all the other white-spored fungi. These papers require no further previous preparation; the fixing of the spores after they have fallen takes place subsequently. The spores which have been received on the writing and on the blue sized-paper are fixed by a solution of two parts mastic, one part sandarac, and two parts Canada balsam in thirty parts alcohol of at least 95 per cent. A small quantity of this lac is poured on to a flat plate, and the preparation of spores laid upon it so that they are not moistened on the upper side. The lac penetrates the paper and the spores, which are thus firmly fixed to it, the time occupied varying greatly with different kinds of spores. Those upon the blue cardboard

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* A further note by Dr. Maddox on M. Miquel's remarks on his Aeroconiscope—see this Journal, iii. (1880) p. 1032—is unavoidably held over.

† Herpell, G., 'Das Präpariren u. Einlegen der Hutpilze für das Herbarium.' (8vo. St. Goar, 1880.) See Bot. Centralbl., i. (1880) p. 1279.

are, on the other hand, fixed by a solution of gelatine, to which some alcohol is eventually added, in order to assist the spores in penetrating it. The relative value of the different processes for any particular species must, however, frequently be determined by actual experiment.

Simple and Speedy Method of Staining Animal and Vegetable Sections.*—After cutting the sections, wash them in water, and allow them to soak for a while.

Transfer them to a solution of anilin violet in commercial acetic acid, the solution to be of the following composition:—

Anilin violet	1 part.
Acetic acid	300 parts.

The sections are to be left in the solution until sufficiently stained, which may be determined by removing them from the solution to clean water. If sufficiently blue, they are then ready to be mounted. If not sufficiently coloured, return to the solution.

The sections are mounted, after staining, by transferring them to a clean glass slide, draining off any excess of fluid, and adding a drop of solution of acetate of potash of the following strength:—

Acetate of potash	1 oz.
Water	½ oz.

Cover, and fasten the cover with varnish, permanently if wished. The advantages of this method are its simplicity and the beauty of the results attained; the disadvantages are that the specimens may fade within a year or two.

This method is taken from Orth's recent work on histology, and is one strongly recommended for demonstrating the structure of cartilage.

Staining and Mounting Pollen.†—At a recent meeting of the New York Microscopical Society, some slides of stained pollen were exhibited (the preparation of the Rev. J. T. Brownell), which are said to have been of special excellence.

The process of preparation was as follows:—A small quantity of pollen having been placed on the centre of the slide, a small drop of staining fluid (anilin dissolved in alcohol) is placed upon it. Then wash by dropping on pure alcohol until all traces of sediment or of stains upon the glass among the pollen grains are washed away. Wipe clean with a dry cloth drawn over the end of a pointed stick, turning the slide rapidly on the turntable. When thus cleaned and quite dry, put on a drop of spirit of turpentine, and then the balsam and cover.

A few kinds of pollen are distorted by the action of alcohol. Some of these can be stained by the use of an ammoniated solution of anilin. Those that will not bear this solution may be mounted unstained.

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* Amer. Mon. Micr. Journ., i. (1880) p. 143.

† Ibid., p. 206.

Dry Mounts for the Microscope.—Mr. A. W. Waters sends us the following remarks suggested by the note on Professor Hamilton Smith's paper in the last number of the Journal:*—

Having mounted several thousand specimens of Bryozoa and other objects in dry mounts, it seems advisable to put the experience thus gained on record, even though there is no claim to any new observation or any important fact observed. Unfortunately it has been necessary to remove a large number of them several times, and in consequence they have been subjected to the severest test of durability, for probably anything which stands the carelessness of Italian railway porters may be considered durable.

All are mounted on glass slips, as this enables both sides of an object to be examined, and they are protected from dust by the cover. Wood slips, which are used by many collectors, are found too liable to warp when old, and the objects are thus damaged or broken. This can be seen in some of the valuable slides in the British Museum. With small cells there are few difficulties, but with deep cells there is great danger of springing, and we may safely conclude that those which after being made a few years stand railway journeys the best may be considered the most durable and most suitable for museum specimens, so as to be available for reference in 50 or 100 years. Some of the specimens referred to are large colonies mounted in glass "built" cells, some as much as half an inch deep, mostly fastened on with gold size, which should be rather thicker than that used for attaching the cover, and with these cases of springing in consequence of percussion have been very few, and these few cases have been the result of special circumstances; on the other hand, with some made with zinc varnish, several cases occurred, and the experience thus gained proves that zinc varnish soon becomes too brittle. Trial has been made of large zinc and other metal rings which have been carefully roughened with the file, but the results have been so unsatisfactory that all metal rings are now discarded as being the most liable to leave the slide. Ebonite rings have stood well, but indiarubber rings about $\frac{3}{4}$ inch in diameter have given the best results, but these are not available for deep mounts, as they are not made much thicker than $\frac{1}{8}$ of an inch. For still smaller things paper and card rings, which can be bought for the purpose, for a very small sum, have been employed, and in all these cases it is advisable to keep a moderate stock on hand, of various sizes, as thus the varnish or cement has time to dry, and there is less danger of the object becoming attached at the side, if left free; but, where it can be done, it is well to attach the object with a spot of cement in the centre of the cell.

Some shellac rings, similar to those mentioned by Mr. Smith,† have been used for some years, but experience has shown that it is well to run gold size round these after they have been mounted and cooled, as otherwise they become too brittle; but with these rings, which are attached by melting the shellac covering the ring, there is however a danger of small crystals forming inside, caused by the vaporization of the shellac when heated.

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* See this Journal, iii. (1880) p. 1038.

† Ibid., p. 1039.

Recently some rings have been attached with liquid marine glue, and the results so far seem very satisfactory; but as the experience of them does not go far back, no sufficient opinion as to their durability can be expressed.

As a precaution, the indiarubber rings have not been used too new, and have in most cases been attached to the glass and in stock some time before the object was mounted; this, it was thought, would minimize the danger of sulphur being deposited on the glass and object; and those mounted several years ago all remain perfectly clear.

Carbolic Acid in Mounting.*—Mr. C. M. Vorce finds that an object which has been macerated in potash can be mounted in balsam without drying, by the following procedure:—Take the object from the potash solution, and arrange it on a glass slip, for which purpose a piece of window-glass, 2 in. square, is very convenient. If necessary, wash it with pure water, using a camel's-hair pencil; then drain away the water, and wipe around the object, add strong potash solution, and after it has been in contact with every part of the object for a few minutes, drain it away, and again wipe the glass as close around the object as practicable. Add carbolic acid (pure) in considerable excess, and warm the slip gently; this causes the object to become opaque, but do not be disconcerted by this. After a time, say fifteen minutes for a small thin object, warm the slip and pour off the acid, and again wipe. Add more clear acid, and transfer the object to a mounting-slip, which is easily done without injuring the object as follows:—Lay the slip on a box or block of about its own width, and ½ inch or more in height, pour the acid from the square slip on to the middle of the mounting-slip, and reversing the square slip, bring it down upon the drop of acid so that the object may first touch it, when, with a little care, the object will settle down into the acid without being much, if at all disarranged. If necessary, it is then arranged under the dissecting Microscope, and when brought into the desired position, if it is clear and quite transparent the acid is drained away, balsam added, and the mount completed.

If found to require cleaning, it can be done with needles and a brush, as in ordinary cases. If clean but not transparent, warm and set away under a bell-glass until it is fit to mount, making another change of acid if necessary. In all cases it is best to take the last change of acid from a bottle kept specially clean and pure for that purpose. Objects macerated in acetic acid can be treated in the same way.

Wax Cells.†—The same writer says, that so much has been lately said about wax cells, a little more cannot be amiss. He has some that are utterly destroyed, and more that are very much injured by the deposit on the under side of the cover. The worst of these were mounted by one who was given to using turpentine to soften the wax; this is probably the cause of the deposit in these slides. His own

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* Amer. Mon. Micr. Journ., i. (1880) p. 207.

† Ibid., p. 208.

mountings are very free from this trouble, though all made with wax-bottomed and asphalt-covered cells. The reason of this, he thinks, is that the cells are mostly made a long time before they are used; his business being such that he can only devote time to microscopy in the mornings and evenings. Hence most of the work is interrupted by twelve-hour intervals. To save time, a lot of cells are made up at once, using double-thick pond-lily wax and brass curtain rings, sometimes a little flattened.

To make the cell, place the ring on the wax and press it down with a slip; then with a wet penknife-blade, cut around the ring outside, and lift it out. The disk of wax is then punctured from below with a needle in two or three places near the middle, and if not already raised a little in the centre, it is gently bent with the finger, so that when placed on the slide it will touch only at the edges. The ring is now placed on the centre of a slip in the turntable, and gently pressed to make it adhere. Then removing the slide, it is held over a lamp, keeping it level; the wax first softens at the ring, and as the softening proceeds towards the centre, the air escapes through the needle-holes, and blisters are prevented as the wax settles down upon the slide. Before the wax actually melts, the slide should be removed, and returned to the turntable to see if it is still centered. If the wax does melt, no harm is done unless the ring slides from its place before it cools. When cool the ring is firmly fixed, and it is then coated on the turntable with Brunswick black, though perhaps shellac would be safer from liability to the "sweating." Having prepared from four to six dozen cells of different sizes, they are laid away in drawers, and after a time, three days to three weeks, as the case may be, the cells are coated again. And when this second coat is dry, any time after a week, the cells are fit for use. In mounting he uses nothing to fasten the object to the wax, but presses it down with a needle or shaved splint of whalebone, or the finger-end in many cases. Objects in fluid are to be allowed to evaporate in the cell, leaving them covered from one night to a day or two, as may be. When the cells are covered, covers are used cut by the author's cover-cutter, just large enough to rest inside the brass rings without falling through. Then the angle between the edge of cover and top of the cell is filled up with wax by means of a pointed knife-blade, using the wax as putty is used on a window. The mounts can now be left for finishing till a leisure time, but it is desirable to apply a light coat of cement before putting them away, and at any time afterward when time can be found he goes over them again, and usually a third time before finishing.

Simple Device for Handling Thin Covers.—Mr. J. C. Douglas writes, that he has long wanted a simple appliance for picking covers out of the liquid in which they may be soaking, selecting them from their box, placing them flat upon the object to be examined or mounted, and picking them off the slide when necessary after examining the object covered. Forceps and needles have grave inconveniences. Chase's mounting forceps [*] simply drop on the

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[*] See this Journal, iii. (1880) p. 508.

cover, and are inferior both in simplicity and utility to the following plan.

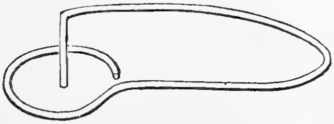
Cut a piece of suitable size from a flat rubber ring, fix this, by a large-headed pin cut short, on to the end of a cedar-stick, driving the head of the pin so as to form a depression in the rubber, wet the rubber, and on pressing it on a cover-glass it will adhere to it, and the glass may be manipulated as desired. To disconnect the rubber from the glass, it is merely necessary to incline the stick so as to detach the rubber at one edge, when the adhesion ceases at once. The apparatus is more durable if a little cementing material be used on the stick, as the pin sometimes draws through the rubber.

A cover can be readily placed flat on a slide, and picked up again if necessary, and when examining objects in fluid, the cover-glass can be put on and taken off very readily. In most cases the necessity for tilting the cover is avoided.

Mounting Clip.—In using the ordinary clips Mr. J. C. Douglas says that he has experienced great inconvenience from the difficulty of moving the slide round while in the clip to apply varnish to the whole circumference of the cover-glass, and the ordinary clips mostly hide the object so that it cannot be properly examined during the process of mounting. Mr. Woodward's device* has the disadvantage of keeping the slide on the turntable until the varnish sets, so that the turntable cannot be used for a number of slides in succession.

Mr. Douglas takes a piece of stout brass wire and bends it into the shape shown in Fig. 24. The ring is as large as the largest cover-glass, so that it does not obscure the object; the pressure is readily regulated by bending the wire, and the point of the wire comes in the centre of the ring. The length of the clip is such as to admit of the slide, held between the end of the wire and the ring, revolving round the end of the wire. The end of the wire is rounded.

FIG. 24.



The mode of using the clip is as follows:—The cover-glass being in position, and gently pressed down, the slide is placed in the clip, in which it can be washed, examined, the edge of the cover-glass varnished, &c.; the holding coats of varnish are put on by hand, revolving the slide in the clip as necessary.

Arranging Diatoms, &c.†—The arrangement of small microscopic objects, such as diatoms, Foraminifera, &c., on slides in regular

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* See this Journal, iii. (1880) p. 507.

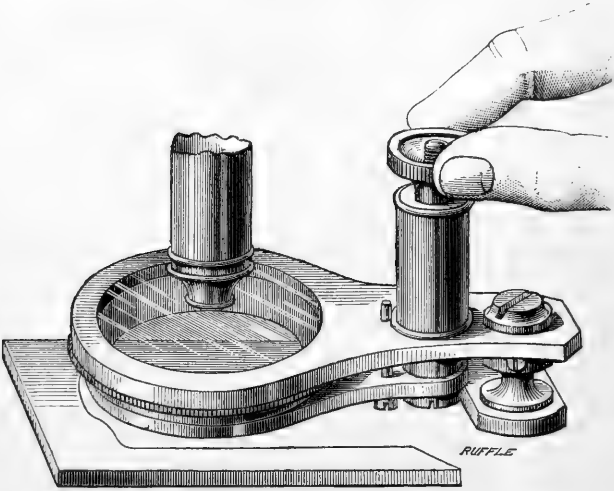
† Mr. J. Deby, in Journ. Quek. Micr. Club, vi. (1880) p. 166.

lines, circles, or patterns, can be facilitated in the following way:—Draw with a pen and ink cross lines, or circles, or any other figure required, on the surface of the plane mirror of the Microscope, then focus down until the image of these lines is seen on the upper surface of the top lens of the condenser. By means of a mechanical finger, or of a steady hand with a rest, no difficulty will be experienced in placing the objects in perfectly regular order.

Holman's Compressorium and Moist Chamber.—Mr. D. S. Holman's new compressor is shown in Fig. 25. The following description is transcribed verbatim from the original:*—

"This apparatus differs from all other compressors in being so arranged that the mica cover is fixed and immovable, while the lower thicker plate of glass is moved up and down by means of a screw nut and spiral spring, an arrangement which enables the student to adjust the apparatus so as to apply with certainty any degree of pressure upon any soft object without risk of breaking large and expensive cover-glasses, crushing the object unexpectedly, or injuring high-power lenses. The writer by its means was enabled to study with great deliberation and certainty the internal anatomy of the larva of the plumed crane-fly (*Corethra plumicornis*). In this case the pressure could be so nicely adjusted as not to disturb in the slightest degree the normal physiological actions of the larval fly; the physiological action of the heart could be readily studied, as well as the significance

FIG. 25.



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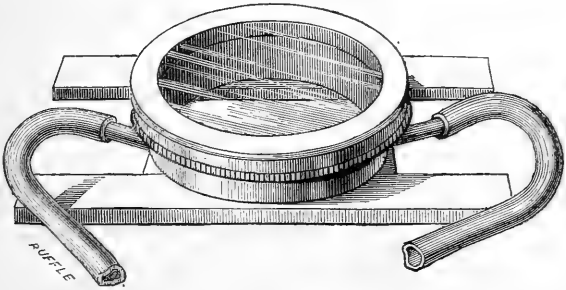
* John A. Ryder, in the 'Journal of the Franklin Institute,' 1880.

of the so-called apolar ganglion-cells of that organ appreciated. Every life-process, in short, was visible through the transparent body of the creature, so that if well studied by the help of this apparatus, the student will have acquired a mental image or epitome of the morphology and physiology of that great group of jointed animals, the Articulates of the naturalist.

Equally good results were got by its use in studying the embryology of the shad, where it revealed to the writer, and for the first time to science, the presence of a so-called polar vesicle in the earliest stages of development.

In Fig. 26 we have a combination of the familiar animalcule cage and the siphon slide, also designed by Mr. Holman. The edge of the cover or cap is bevelled, so that by rotating it against the inflow and outflow tubes of the siphon arrangement, a very convenient and effective compressor is obtained. The apparatus is equally as valuable as the compressor before described, because of the certainty with which one can gauge the amount of pressure which is applied; also on account of the facility with which water may be renewed in it when used as a "moist chamber" for studying growing fungi, without in the slightest degree disturbing these delicate plants. The value of the apparatus is further enhanced by the facility with which it may be used as a siphon-slide for keeping aquatic larvæ, worms, &c., alive for a lengthened period for study or exhibition. It is equally useful as a dry compressor for holding, studying, and drawing minute soft-bodied insects in the living state."

FIG. 26.

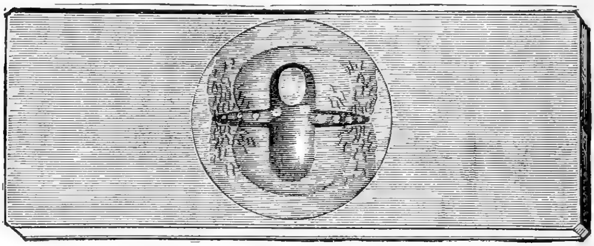


Holman's "Life Slides."—Figs. 27, 28, and 29 are three "life slides," which were invented by Mr. Holman some years ago, though we do not remember that they have been figured in this country.

(1) "*Life Slide.*"—This slide (Fig. 27) consists of a 3×1 inch glass slide, with a deep oval cavity in the middle to receive the material for observation. A shallow oval is ground and polished around the deep cavity, forming a bevel. From this bevel a fine cut extends, to

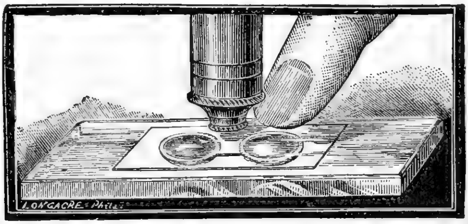
furnish fresh air to the living low forms of life. They will invariably seek the bevelled edge of the cavity, and so are in the reach of the highest powers. Owing to the supply of fresh air, the living animalcule may (it is said) be kept for weeks. It is adapted, too, for studying the circulation of the blood in the tail of the tadpole.

Fig. 27.



(2) "*Life and Current Slide.*"—In a slip of plate-glass (Fig. 28), two oval cells are ground and polished, which are connected by a very shallow channel. If the cells are partly filled with blood and covered by a thin cover-glass, the expansion of the air in one cavity will drive the blood through the channel, and then it may be observed under the most favourable condition, even for a high power. The apparatus is so sensitive that the current may be changed by bringing the finger near one of the cavities, and arrested by moving the finger away.

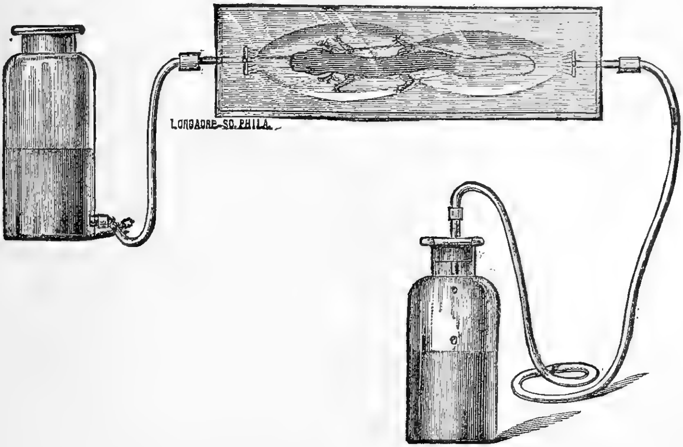
Fig. 28.



(3) "*Siphon Slide.*"—This (Fig. 29) consists of a slip of thick plate glass, with two shallow oval cavities and a deep groove in the middle, to hold a small fish or Triton, and retain it without undue pressure in a fixed position. Small metallic tubes communicate with the extremity of the deep groove. Rubber tubes are connected with these metal tubes, one of these being intended for the entrance and the other for the exit of any fluid, cold or hot. When in use it is only necessary to place the animal with some water into the groove, cover it with the glass cover, immerse one of the rubber tubes in a jar of water, and, by suction, draw the water through the apparatus. If the slide is placed on the stage of a Microscope the jars should stand lower,

so as to make the slide the highest part of the siphon, and the pressure of the atmosphere holds the cover tight.

FIG. 29.



This apparatus is adapted for the gas-microscope, as by a constant flow of cold water the Triton can be kept in the focus of the condenser for hours.

Mapping with the Micro-spectroscope.*—Mr. J. Deby says that when mapping with the micro-spectroscope the difficulty of measuring exactly the position of fine lines or absorption-bands is often great, but that he finds that in most practical cases the micro-spectrum can be thrown upon a sheet of white paper by means of an ordinary camera lucida placed over the eye-piece of the spectroscope, strong light by means of a condenser being thrown through the liquid under examination. By means of an ivory rule, finely divided, and brought back to a known line, say D, all other lines or bands may be directly measured off on the rule, and, if desired, the exact results in millionths of a millimetre may then be computed by any of the known interpolation formulæ, such as are given in Mr. Suffolk's useful little book.†

Tubes for conveying Moist Specimens, Diatomaceæ, &c., by Post.‡—J. J. M. recommends a thin membrane of gutta-percha, such as is used by surgeons, cut to the required size. The joint is made by dipping a camel-hair brush in chloroform, drawing it along the edge, say half an inch wide, and then placing the part to be joined to it before the chloroform has evaporated. If the tubes are only three parts full, it will allow of a little pressure, should it occur in transit. The cover can be made by rolling brown paper over a ruler or other suitable form, fastening with paste, as firework cases are made, allowing to dry, then cut to lengths required.

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* Journ. Quek. Micr. Club, vi. (1880) pp. 165–6.

† 'Spectrum Analysis as applied to Microscopical Observation.' (8vo. London, 1873.)

‡ Sci.-Gossip, 1881, p. 17.

Glass Crystals.[*]—The crystal, Fig. 30, is that of ordinary window-glass, which is formed by cooling down large masses of fluid glass for several days to a temperature slightly higher than its point of viscidity. These crystals were discovered about ten years ago, and at intervals up to the present day Mr. W. D. Herman and Mr. G. E. Davis have spent much time in investigating their nature and in photographing them. Their close relationship to rock-structure make them exceedingly interesting, as well as the large number of forms which are often found in the same square inch of glass. Some mixtures of glass give these star-crystals only, while in others there are none found save prisms; and these latter form excellent polariscope objects.

Fig. 30.

The figure was prepared by photographing the crystal with the aid of a $\frac{1}{4}$-inch objective, the collodion-film being then transferred to the wood-block.

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[*] 'Northern Microscopist,' i. (1881) pp. 21–2. 2 figs.

PROCEEDINGS OF THE SOCIETY.

Meeting of 8th December, 1880, at King's College, Strand, W.C., James Glaisher, Esq., F.R.S., in the Chair.

The Minutes of the meeting of 10th November last were read and confirmed, and were signed by the Chairman.

Mr. Shadbolt rose to make some observations upon the aperture question, but

The Chairman reminded him that as no notice of his intended communication had been given to the Secretaries, it did not appear upon the Agenda paper, and it would not be possible, therefore, to take it then.

Mr. Shadbolt inquired whether free discussion was to be stifled in the Society, or whether the old rules were to be regarded as still in force. In his Presidency every Fellow met with a fair hearing.

The Chairman said that he, as chairman, could not give exceptional precedence to any communication of which they had not received at least twenty-four hours' notice. He would, however, put it to the Meeting whether Mr. Shadbolt should be heard at once, or in the ordinary course of the business.—It was decided, upon a show of hands, with one dissentient, to proceed with the business in the order in which it appeared on the Agenda paper.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society given to the donors.

	From
Dodel-Port, Dr. A. and Carolina. Anatomisch-Physiologischer Atlas der Botanik für Hoch- und Mittelschulen. Part 4. 6 plates. (Fol. Esslingen, 1880.)	*The Authors.*
" " " Text zum . . . . Atlas . . . . Part 4. 24 pp. (4to. Esslingen, 1880.) ..	*Ditto.*
Slides with Wax Cells covered with White Zinc Cement for Fluid Mounts	*Mr. W. H. Walmsley.*

Mr. John Mayall, jun., described, by means of a drawing on the black-board, the fine adjustment of Mr. Crouch's histological Microscope (see p. 114), also a new mechanical stage to be used with the Tolles-Blackham Microscope (see p. 115), the chief features of which were extreme thinness and the removal of the milled heads to a position in which they did not project beyond the margin and so interfere with the swinging substage, as was usually the case.

The Chairman, in announcing the election of the eight gentlemen who had been balloted for, said that this made up the number of new

Fellows elected during the year to forty-seven, irrespective of eight more who were nominated that evening, and making 105 elected during the last two years. Taking as he did the greatest interest in the welfare of their Society, and in the continued prosperity of the Journal, he most heartily desired that these additions would not only continue, but would go on still increasing.

Mr. Wallis exhibited and described his new form of rotating substage, carrying achromatic condenser, dark-field illuminator, dark wells, polariscope, and selenites (see p. 125).

Mr. Crisp said that while few would probably avail themselves of such an arrangement as this in connection with a large instrument used at home with every accessory within reach, yet in the case of a portable or travelling Microscope it was a different matter, and he was inclined to commend a contrivance of that kind for such a purpose.

Mr. Crisp exhibited and described Parkes's Child's Microscope, Holman's new compressorium (a drawing of which was made upon the board), and his moist chamber, which was a combination of the animalcule cage and the siphon slide (see p. 142), also Beck's "lever and spring cell-making machine" with removable legs and clamp for table, and their rotating cell-holder exhibited at the last meeting, but with the rubber-cells *in situ* (see vol. iii. p. 1041, and *ante*, p. 124), also some wax cells covered with white zinc cement for fluid mounts, sent by Mr. W. H. Walmsley, of Philadelphia.

Mr. John Mayall, jun., exhibited and described a spiral diaphragm which he had devised, drawings on the board and a cardboard model being used in illustration (see p. 126).

The Chairman announced that a Fellow had offered to the Society a fund to be applied for a gold medal, to be bestowed under certain conditions upon any person of any nationality who shall have originated any important improvement in the construction of the Microscope or any of its accessory apparatus, or have in other ways eminently contributed to the advancement of the Microscope as an instrument of research. Another Fellow had also offered a similar fund for a medal to be given in respect of researches in any subject of natural science carried out wholly or in great part by means of the Microscope, or of the recipient having in other ways eminently contributed to the advancement of research in natural science in connection with the Microscope, the two medals to be known respectively as the "Microscopical" and "Research" Medals of the Society. The Council had decided to bring the subject formally before the next Meeting, with the view to the acceptance of the terms on which the funds were offered.

Dr. C. T. Hudson's paper "On *Œcistes Janus* and *Floscularia trifolium*, two new species of Rotifers," was read by Mr. Stewart, by whom enlarged copies of the illustrations were drawn upon the board (see p. 1). The latter Dr. Hudson described in a separate letter as a "great prize," being a perfectly new Floscule, with only three lobes, and much larger than any of the known species; and the former as being most interesting from its trochal disk, being, as it were, a link between that of *Melicerta* and that of *Œcistes*.

Mr. Crisp read a letter from Mr. John Hood, of Dundee, the discoverer of the animals, stating that in consequence of continued bad weather he had been prevented from securing the specimens which he had hoped to send for exhibition at the meeting.

Mr. Ingpen said he had the pleasure of seeing the specimens described by Dr. Hudson, as Mr. Hood had sent them to him in the first instance, and he had put him in communication with Dr. Hudson on the subject. There was just one point which seemed to have been overlooked (though no doubt it had not escaped so careful an observer as Dr. Hudson), and that was as to the length of the antennæ, which were quite of a rudimentary character. In *Tubicolaria* they were very large and conspicuous, but in this new species they were lower down and were quite small, with two little setæ on them.

Mr. Wenham's Note "On a secure Method of Setting the Front Lens of Oil-immersion Objectives," communicated through Mr. Mayall, was read (see p. 121).

Mr. Stodder's Note on Tolles' Opaque Illuminator for High Powers was read, in which, after referring to Professor Rogers' paper (see vol. iii. p. 754), he writes:—"It is of course a well-known fact that discoveries and inventions are sometimes made by different persons simultaneously and independently, and also that such discoveries and inventions are sometimes claimed by a second party, who only acted on a hint or published description by the original discoverer. It is for this that priority of publication is always insisted on by scientific men for proof of priority. I will now show that this invention of Tolles was amply published prior to any date mentioned by Professor Rogers, in periodicals not obscure, but of wide circulation in Europe and America. . . . . Professor Rogers refers to the 'Annual of Scientific Discovery,' Boston, 1866–7, which records the exhibition in 1866. This publication had a wide circulation, and was sufficient publication to establish priority; but in the 'Monthly Microscopical Journal,' London, iii. 1870, p. 49, is a description of the invention under the caption of 'Tolles' new Method of the Illumination of Opaque Objects under High Powers,' giving a description of the invention and its performance. This is credited by the London Journal to 'Dental Cosmos,' as copied from 'Boston Journal of Chemistry,' November 1869, p. 52, 20,000 copies in circulation. Moreover, it was advertised in the catalogue of Tolles' instruments, and taken out only because he found them unprofitable to make.

"Here are publications of the invention in four scientific periodicals, amply sufficient to secure the original inventor his priority.

Professor Louis Agassiz once, in a lecture, made the remark that some people expressed great surprise that scientific men were so sensitive about their claims to original discovery. He said it was for the reason that such was their most valuable, perhaps their only, property."

Mr. Crisp stated the effect of a note from Mr. Tolles as to his original swinging substage, and one from Mr. J. H. Fisher on an undescribed Flagellate Infusorion (*Laguncula piscatoris*).

Mr. Stewart made some verbal observations on some Echinometridæ, explaining the structure of the four varieties of Pedicellariæ known as the tridactylate, the ophiocephalous, the trifoliate, and the gemmiform. Numerous specimens were exhibited, and the special adaptation of some to the peculiar conditions of their existence pointed out.

The rest of the Business on the Agenda was then arranged to be taken as read, or postponed till January, and the Chairman called upon Mr. Shadbolt for his remarks.

Mr. Shadbolt reiterated the views expressed in his Note read at the last meeting (see vol. iii. p. 1089), and said that he was sorry to find that great misapprehension existed on the subject, which had been allowed place in the Journal. He desired to state most emphatically, and could prove it, that if they had a radiant point, whether it were immersed in air or balsam, or any other medium, the quantity of rays from such radiant point must be the same identically whatever the medium was; and no lenses could be produced which would embrace more than the whole number of these rays. It was no doubt correct that the lenses made for immersion use did, under certain conditions, give some advantages over others in the shape of resolving power which the others did not.

He hoped that they should have a subject of such importance brought fairly before the Society at a future meeting, and that time would be found for it to be discussed freely, and without any attempt to put it aside, as it was important that it should not go forth as the dictum of the Royal Microscopical Society that more than the whole could be taken in.

Mr. Crisp said that Mr. Shadbolt's view was founded on a fundamental error in optics; but he only wished to point out now that the question in respect to his communication had not been as to any objection to free discussion, or putting aside of any point, but solely whether communications of which they had had previous notice should or should not take precedence of those in regard to which no notice at all had been given. The rule that had been laid down by the Council was, a week's notice, but he had in practice always entered on the Agenda whatever reached him up to the night before the meeting. Anything received later than that, must of necessity go in at the bottom of the list.

The following Objects, Apparatus, &c., were exhibited:—

Mr. Bolton:—*Spirostomum teres* (Infusorion).

Mr. Coppock:—Rotating Cell-holder, with Rubber-cells *in situ* (see p. 124), and Lever and Spring Cell-making Machine with removable legs, and clamp for Table.

Mr. Crisp:—Crouch's Histological Microscope (see p. 114); and Parkes's Child's Microscope; Holman's new Compressorium and Moist Chamber (see p. 142); Tolles's thin stage (see p. 115), and *Frustulia saxonica* and *Rhizosolenia styliformis*, mounted in Monobromide of Naphthaline, by Herr E. Weissflog of Dresden.

Mr. J. Mayall, jun.:—Spiral Diaphragm (see p. 126).

Mr. Stewart:—Various Echinometridæ.

Mr. Wallis:—Rotating Substage (see p. 125).

Mr. Walmsley:—Wax Cells, covered with white zinc cement for Fluid Mounts.

New Fellows.—The following were elected *Ordinary Fellows*:—Messrs. J. A. Close, M.B., L.R.C.P. Edin., L.R.C.S. Edin., E. M. Holmes, F.L.S., E. R. McDermott, T. Newman, T. Powell, J. Swift, W. H. Symons, F.C.S., and J. A. Thacker, M.D.

SCIENTIFIC EVENING.

The first Scientific Evening of the Session was held in the Libraries of King's College, on the evening of Wednesday the 1st December, 1880.

The following were the objects, &c., exhibited:—

Mr. Baker:
- Nos. 1, 4, 7*a*, and 8, Microscopes by Zeiss.
- Professor Abbe's Immersion Condenser.
- Camera Lucida (2 prisms) by Zeiss.
- New Microtome by Zeiss.
- $\frac{1}{12}$, $\frac{1}{16}$, and $\frac{1}{20}$ Homogeneous-immersion Objectives by Seibert.
- $\frac{1}{8}$ (140°) Homogeneous-immersion Objective by E. Gundlach.
- Dr. Royston-Pigott's Transfer Finder.
- Dr. Maddox's modified Aeroconiscope (see p. 134).

Messrs. R. and J. Beck:
- New large best Microscope and Desmidiaceæ.

Mr. A. W. Bennett:
- Absorptive glands of carnivorous plants (*Drosera* and *Pinguicula*).

Mr. W. A. Bevington:
- Skin of boar fish.

Mr. T. Bolton:
- *Spirorbis nautiloides* and *Ilyocryptus sordidus*, from Sutton Park, by Mr. Forrest.

Mr. H. Crouch:
- Microscope with new swinging substage and mirror.

Mr. T. Curties:
- *Hœmatomyzus elephantis* (parasite of elephant).

Mr. G. E. Davis:
Crystals of glass, and photographs of the same with $\frac{1}{4}$-inch objective.

Mr. L. Dreyfus:
Closterium and *Micrasterias* containing *Amœbæ.*

Mr. C. G. Dunning:
Diatoms—*Rhipidophora nubecula* on *Laomedia geniculata.*
New form of portable Microscope.

Mr. F. Enock:
Eyes of spider, *Salticus tardigradus,* and winged parasite of swallow, *Stenopteryx hirundinis.*

Mr. F. Fitch:
Snout-fly, *Rhingia rostrata.*

Mr. C. J. Fox:
A diffraction effect.

Mr. A. de S. Guimaraens:
Fossil wood with algæ, from Thanet.

Mr. H. Hailes:
Foraminifera—*Calcarina hispida.*

Messrs. J. and W. How:
Sanidine trachyte, ejected block from Vesuvius, and sections of chalk, &c.

Mr. W. Joshua:
Chantransia investiens, parasitic on *Batrachospermum moniliforme,* and some other species of algæ supposed to be new.

Mr. W. S. Kent:
Collared Monads (Choano-Flagellata, S. K.), living and preserved. Genera *Monosiga, Codosiga,* and *Salpingœca;* also those of the calcareous sponge, *Leucosolenia coriacea.*

Mr. A. D. Michael:
Plumularia echinulata, with extended tentacles.

Mr. E. M. Nelson:
Amphipleura pellucida. Slide No. 84. Diatom series of Messrs. P. T. Cleve and I. D. Möller. Collected by O. Nordstedt at Grimstorp, Sweden. With Powell and Lealand's water-immersion $\frac{1}{16}$ objective and a magnification of 1700 diameters, illuminated by the vertical illuminator.
(No. of striæ to the inch transverse, 96,000; No. counted, 96.
,, ,, ,, longitudinal, 80,000; ,, ,, 6).

Mr. G. Nicholson:
Section of petiole of *Victoria regia.*

Mr. T. Norman:
Section of palate of eagle ray.
Section of tooth from saw of saw-fish.
Section of sunstone from Norway.

Messrs. Powell and Lealand:
Amphipleura pellucida in balsam, with $\frac{1}{12}$ oil-immersion objective and oil-immersion truncated condenser.

Mr. B. W. Priest:
Siliceous casts of sponge, *Colon pandina.*

Mr. H. C. Richter:
Drawings of spiders, *Salticus scenicus* and *S. tardigradus*, house-fly and dung-fly.
Mr. J. Smith:
Pleurosigma attenuatum with $\frac{1}{16}$ object-glass, and Podura scale with $\frac{1}{10}$ object-glass, with illumination as described in his paper (see Journal, iii. (1880), p. 398).
Mr. J. H. Steward:
Head of silkworm-moth and human intestine injected by Professor Quekett.
Improved form of portable Microscope.
Mr. Charles Stewart:
Eye of turtle, showing optic disk, retina, choroid, and sclerotic.
Messrs. Swift and Son:
Pleurosigma angulatum with radial traversing substage illuminator.
Mr. A. Topping:
Head of *Cysticercus*, stomach of *Dytiscus*, and teeth of medicinal leech.
Rev. J. E. Vize:
Spores of coffee fungus, *Hemileia vastatrix*.
Mr. F. H. Ward:
Sections of twig and petiole of horse-chestnut, leaf of mistletoe.
Mr. E. Wheeler:
Fructification of acrogens, lichens, fungi, and algæ.
Prothallium of fern with antheridia and archegonia. Spermogones and apothecia in lichens. Acrospores and resting-spores in fungi. Tetraspores and antheridia in algæ.

MEETING OF 12TH JANUARY, 1881, AT KING'S COLLEGE, STRAND, W.C.
THE PRESIDENT (DR. BEALE, F.R.S.) IN THE CHAIR.

The Minutes of the meeting of 8th December last were read and confirmed, and were signed by the President.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society given to the donors.

	Fro
(Hooke, Dr.)—Microscopic Observations; or Dr. Hooke's Wonderful Discoveries by the Microscope, &c. 65 pp., 33 plates. (Fol. London, 1880.)	*Dr. Maddox.*
Trevisan, Il Conte V.—La Fillossera e l'Avvenire della Viticoltura in Italia. 78 pp. and 2 plates. (8vo. Milano, 1880.) And 22 other pamphlets and papers by the same author	*The Author.*
Photographs of glass crystals	*Mr. G. E. Davis.*
Slides of Diatomaceæ from Illinois, U.S.A.	*Mr. B. W. Thomas.*

The List of Fellows to be recommended to the Society for election as Members of the Council at the ensuing annual meeting was read in accordance with the 44th bye-law.

Mr. Suffolk and Mr. Curties were appointed Auditors to audit the Treasurer's accounts.

The President said that with regard to the subject which was mentioned at the last meeting, that of the proposed "Microscopical" and "Research" medals, which had been generously placed by two Fellows at the disposal of the Society, the matter had been further discussed by the Council, and at their meeting that evening it had been decided to ask the gentlemen in question to withdraw their offer. The question was not free from considerable difficulty. It would be remembered that some years ago the Quekett medal was abandoned, and the interest of the fund applied to the purchase of books, so that it was felt to be difficult now to establish other medals. He was sure that the Society would feel none the less indebted to those gentlemen who had so liberally come forward.

Mr. Crisp said that they had now so often to adjourn without disposing of the business on the Agenda paper, that it was proposed to read it in future at the commencement of the meeting, so that it might be seen what matters would be most likely to interest those present.

The President announced that some new gauges and screw tools for the "Society" screw had been made, and could be obtained of the Assistant Secretary.

Mr. Crisp exhibited and described the various Microscopes, &c., of which a list is given at p. 172.

Professor P. M. Duncan gave a résumé of his paper "On a Radiolarian and some Micro-Spongida from considerable depths in the Atlantic Ocean," illustrating his remarks by diagrams and by specimens exhibited under Microscopes in the room.

Mr. C. H. Bassett's note on a new homogeneous-immersion fluid of 1·5 refractive index was read (see p. 123).

Mr. Shadbolt read his paper on "The Apertures of Microscope Objectives," first quoting the following remarks of Mr. Wilson on his original note, read at the November meeting,* viz.:—

A. "Mr. Wilson said that Mr. Shadbolt appeared to have alto-

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* See vol. iii. (1880) p. 1091.

" gether misapprehended the note at p. 875. That did not refer to " '*angle*' at all, but to '*aperture*,' and it was now well established " that they were not synonymous terms; he did not therefore follow " Mr. Shadbolt's demonstration as to the angle being necessarily less " than 180°, which he imagined that no one disputed. The original " note and Mr. Shadbolt's letter related in fact to two distinct " matters."

B. " Mr. Wilson said that Professor Stokes' paper was a refuta- " tion of the very fallacy on which Mr. Shadbolt's reasoning was " based. The expression '*angle of aperture*' had never, in fact, been " a measure of the relative apertures of even dry objectives, and on " the introduction of immersion objectives, it had ceased to have any " definite meaning whatever."

Mr. Shadbolt's paper then proceeded as follows:—

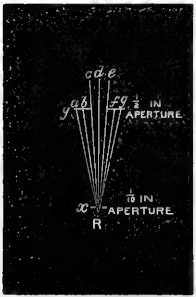
" I presume no one will be found hardy enough to contend that the *total amount of light* emitted from a radiant point under a given fixed illumination would be greater if the said radiant point were in oil or any other dense transparent medium, than if it were in air. In point of fact, we may regard this total amount of radiant light as a fixed quantity while the illumination of the object remains unaltered.

" *Quotation* A.—It is quite possible that I may have to some extent misapprehended the note at p. 875, seeing that those who employ the term 'numerical aperture' have never, that I am aware, condescended to explain in definite terms what they mean by it. In point of fact, I deny its existence altogether as 'aperture,' which term means 'opening,' and nothing else. The term aperture may be fitly applied in two ways, viz. by quoting its actual size, or by quoting the angular pencil of light which it allows to pass through it: the '*angular aperture*' of a lens, whether dry or immersion, is just the measure of the pencil of light which it will bring to a focus, with or without the aid of other lenses behind it: it is therefore evident, as shown in my previous note, that no lens can really have an aperture of 180°.

" The absolute aperture of a lens—say half an inch—one-tenth of an inch—one-hundredth of an inch—gives no measure of the proportion of a pencil of rays from a radiant point that it will allow to pass through, without at the same time its focal distance is quoted; on the contrary, if its '*angular aperture*' be quoted it gives a very exact idea of the proportion. The accurate measurement of that aperture may be a difficult matter; but easy or difficult, that does not affect the question at issue. Thus a Microscope objective, with a *half-inch* aperture, may, and generally does, admit a smaller angular pencil of rays than one of *a tenth of an inch:* in fact, it all depends upon the distance of the said apertures from the radiant point. Now, with an angular pencil of 180°, there is no question of distance of the aperture from the object; it must be absolutely in the same plane with the object, and no question about its size, so that it includes the radiant point. The words '*angular aperture*' therefore convey a correct and definite idea of the pencil of rays admitted; the words 'numerical aperture' convey no such meaning, nor indeed to my mind any meaning at all. If the '*angular aperture*' of a lens be correctly gauged, it forms a very exact measure of the proportion of the radiant pencil of (say) 180° that the said lens will admit, and I am therefore constrained to meet with a very decided negative the statement in quotation B relative to this point. Angular aperture means now just as much and just as little as it ever did.

"Of course mere aperture is not a fair measure of comparison between two or more lenses any more than mere achromatism, or mere correction for spherical aberration; but *cœteris paribus*, it is a very important element in the comparison, and 'angular aperture,' as above defined, has exactly the same value whether in a dry or an immersion lens, neither more nor less.

Fig. 31.



"I am really almost ashamed to give a diagram to illustrate so elementary a matter as the angle of aperture; but in the face of the contention which has been advanced, it seems needed for the completion of my argument—to convince those at least who have not studied the phenomena of optics.

"Let R (Fig. 31) be a radiant point, and $a\ b\ c\ d\ e\ f\ g$ rays proceeding therefrom, it is clear that an aperture of $\frac{1}{10}$ of an inch in diameter placed at x admits the whole of the rays depicted, while the aperture of $\frac{1}{2}$ inch diameter at y admits only three of them. The 'angular aperture' of the small diameter is a R g, while that of the larger one is only c R e.

"It is therefore clear that 'numerical aperture' cannot be equivalent to absolute aperture: it is alleged to have nothing to do with 'angular aperture,' but to be something 'quite different.' Then what is it? I want to see it, or at least to have a diagram of its supposed form; in fact, any information about it will be thankfully received.

"Mr. Wilson says 'the original note' and my letter relate to *two distinct matters*, as if they were in no way comparable with one another—such, for instance, as the time of day with the length of a man's nose. Well, I don't object, only why do Mr. Wilson and others constantly persist in comparing the 'angular aperture' of an impossible lens with this mysterious 'numerical aperture,' of which we have no definition?

"If it were possible practically to employ an angular aperture of 180° in lenses, whether dry or immersion, the *whole* of the rays emitted from a radiant point would be admitted by both lenses if the object under inspection were immersed in air, and by the immersion lens, in a suitable liquid, if the object were mounted in balsam; it is, therefore, simply absurd to talk about an 'aperture' which admits *more than the whole* of that which has to be admitted.

"To speak of a lens of 180° angular aperture in air (or anything else) admitting only a pencil of 81° 58′ is a contradiction. A lens that will only admit such a pencil is a lens of only that angular aperture.

"If a dry lens be employed on a balsam-mounted object, a portion of the radiant pencil is turned back by total reflection at the air-surface of the covering-glass, when the incidence of the rays exceeds the 'critical angle,' so that only a pencil of not exceeding 81° 58′ can escape from out of the mounting of the object to fall upon the front of the dry lens; but that does not affect the capacity of the lens, which is merely placed in circumstances wherein its full powers cannot have play.

"It may be, and is, a very good reason for using an immersion lens instead of a dry one, but it is monstrous to assert that the latter has an 'aperture' exceeding that of 180° in air. The object is the thing at fault, and not the lens; the object has been placed in a condition which prevents more than a pencil of 81° 58′ emanating from it.

"It follows also that the 'numerical aperturists,' if I may coin such a phrase, have fallen into another error about this matter. It has been assumed by them that the difference between the pencils of light admitted respectively by the dry and immersion lenses from a balsam-mounted object, bears a direct proportion between the refractive indices of air and the fluid used for immersion; but this is *not the case*, for it is evident from a consideration of the preceding facts detailed, that the difference can only be that between twice the critical angle and the largest immersion angular aperture of the lens in use, the critical angle being a constant quantity in any given medium in contact with air, so that in the case of immersion lenses having an angular aperture of less than 81° 58′ there would be no difference at all.

"I am far from undervaluing the advantages of immersion lenses. In certain cases they are invaluable; the working distance in front of the lens is greater (an important consideration with very high powers), the refraction by the front lens being effected entirely or chiefly at its back surface; and Mr. Stephenson has pointed out how the immersion lens can be profitably adapted so as to avoid the necessity for correction for the varying thicknesses of the glass covering the object. The only drawback that occurs to me in their use, is the necessity of interposing a film of suitable fluid; but I have yet to learn that immersion lenses can be constructed to include a larger angular pencil of light than can be included by a dry lens.

"If, instead of characterizing my statement as a 'fallacy,' my critic had been good enough to point out any flaws he could discover in the argument of my note on this subject, which he had just heard read, and which appears at pp. 1089, 1090, and 1091, vol. iii., of the Journal of the Royal Microscopical Society, it would have been a far more satisfactory mode of proceeding: but, in fact, my statement is not at all opposed to what is demonstrated in Professor Stokes's paper, published in the Journal of the Royal Microscopical Society for July 1878, vol. i. p. 141 *et seq.*"

Mr. Shadbolt then referred (in six lines) to what he conceived to be the circumstances under which Professor Stokes's paper was written, and proceeded :—"It is almost superfluous to remark that this gentleman understands perfectly what he intended to convey, and carefully protected himself by qualifications and explanations of his statements, where, had he not done so, room might have been found for misrepresentation. For instance, at p. 140, vol. i., I find the following, viz. :—

"C. 'It is intended simply and solely to show the *fallacy of the supposed limit* of 2 γ assigned to the aperture within a medium.' And at p. 139, the value of γ is given as $= 40° 59'$; but Professor Stokes nowhere asserts that there is such a limit with a dry lens, for the simple reason, no doubt, that there is no such limit, and he is far too astute to 'travel beyond the record.'

"Who is responsible for promulgating the fallacy in question I am not aware; but I can perhaps make a good guess as to how it arose. I quote also the following from p. 139, which I find in Professor Stokes's paper, viz. :—

"D. 'To disprove an alleged proposition, the shortest and least invidious plan is often to show by one or more particular instances that it is untrue.'

"This I propose doing with regard to 'the supposed limit' of 2 γ in air, and I shall take the liberty of copying Professor Stokes's diagram from p. 141, vol. i., and of adding thereto some few lines in illustration of my argument, using the same letters of reference as those on the original so far as they go.

"O, Fig. 32, is the centre of the large segment of the sphere H A L. The rays Q H–Q L diverging from the focus Q within the glass (or medium) are refracted at H towards K, and at L towards M, as if they proceeded from q, the angle H q L being 81° 58′.

FIG. 32.

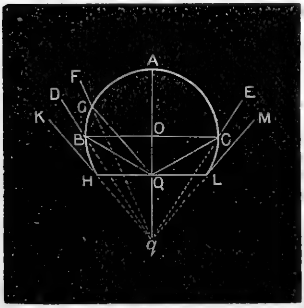
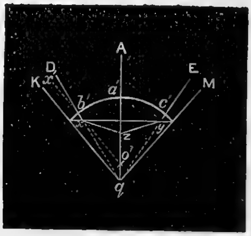


FIG. 33.



"It is assumed by Professor Stokes that Q is a real focus of no aberration, and that achromatism, &c., will be dealt with by the back combinations; and it is further suggested that in order to make the lens of practical use, the excessively large segment of a sphere here depicted shall be reduced to a hemisphere, leaving the space between the lines H L and B C as working distance for balsam, covering-glass, and immersion fluid.

"I adopt both of these suggestions for my illustration.

"Draw B C through the centre O parallel to H L, and D *q*, E *q*, through the points B and C respectively, and join B Q and C Q, B Q C will be the 'angular aperture' of the hemispherical lens, which will be about 113° or 114°, and D *q* E the angular pencil, after refraction, about 66°, the spaces between the radiant point Q and the front of the lens being occupied by media of about the same refractive index as the glass.

"Suppose, now, that we draw the ray Q G at an angle of 40° 49′ with the axis (the critical angle), and F *q* through the point G, it becomes possible to arrive at some faint idea of the probable way in which the fallacy of the 'supposed limit' may have given rise to the notion of an immersion lens being able to refract rays that a dry one could not; for if the lens B A C were in air, it is manifest that the ray F G Q would, on reaching the surface B O, be refracted to O, and all the rays between F *q* and D *q* would suffer internal reflection, never getting out of the lens at all, and erroneously conclude that they must therefore necessarily be lost by a dry lens.

"But those who argue thus overlook the simple fact that it is by no means necessary to let the lens intercept the pencil D *q* E at the points B C if it be intended for use as a dry lens; nor, in fact, is it necessary to employ so large a portion of the sphere as a hemisphere, nor even to use a lens of the same radius of curvature as is suitable for the immersion lens.

"However, to show what can be done with a lens of the same radius of curvature, draw the pencils K *q* M and D *q* E, Fig. 33, exactly similar to those in Fig. 32, and let the lens *b′ a′ c′* of the same radius of curvature cut the said pencil at the points *b′ c′*, which are situated so as to form an angle of 81° 58′ with the centre *o′* of curvature of the lens. The lines D *q*, E *q* will be refracted at *b′* and *c′*, and falling on the flat front surface at *x* and *y*—at a smaller angle of inclination with the normal than the critical angle—will pass out of the lens and come to a focus at *z*, the angle *x z y* being a larger angle than B Q C, that of the immersion lens.

"The thickness of the lens *b′ a′ c′* for a dry objective can be varied to a great extent to suit the exigencies of construction without loss of aperture, because the front surface performs a very large part of the refraction, while in the immersion lens the back surface of the front lens alone is effective; but in any case there must be more 'working distance' available with an immersion lens than with a dry one, hence one of its most important advantages.

"I have now demonstrated beyond dispute the following facts, viz.:—

"That a dry lens can have as large an 'angular aperture' as an immersion one, and that the assumed difference of aperture between dry and immersion lenses does not exist;

"That no lens can have an 'aperture' of any kind which exceeds that of 180° angular in air; and

"That consequently the table of 'numerical apertures' published on the cover of the Journal is erroneous and misleading, and should at once be discontinued.

"*Addendum.*—Since writing the preceding I have had occasion to refer to the number of the Journal for Dec. 1879, vol. ii. No. 7, and while turning over the leaves I to-day (3rd January 1881) stumbled over the original communication of our treasurer, Mr. Stephenson, which appears to throw some light on the so-called 'numerical aperture.' The article to which I allude appears at p. 839.

"I have no doubt I read it at the time of publication, as I distinctly remember some of the other articles in the same number; but evidently it did not arrest my attention, and indeed had it done so it is not probable that I should have gone out of my way to have opposed it as it then appeared, that is, as the simple expression of Mr. Stephenson's opinion, which of course he was fully within his rights in publishing, and had it so remained I should probably never have taken any notice of it, for, naturally, I do not feel called upon to record my dissent from every proposition with which I may happen to disagree; but the persistent way in which the expression 'numerical aperture' has been of late thrust forward in the Journal, and the repeated publication of the 'table,' which I now perceive has been extracted from this paper, on the cover, culminating in an impossible explanation of a non-existent phenomenon, ostensibly on editorial authority, have upset my equanimity, and I find it high time to protest against the appearance of this error having been adopted by the Royal Microscopical Society or its authorities as an article of faith.

"I have again twice perused the article with careful attention, and I am more than ever discontented with the term '*numerical aperture*' and the assumptions which follow as being altogether erroneous and misleading, for I now find, as I had already conjectured, that the mysterious 'numerical aperture' is not an aperture at all, but a mere product of an arbitrary calculation; and the best of the joke is, that it is actually based upon the much-maligned 'angular aperture'—the vaunted 'numerical aperture' being the product of the *sine of half the angle of aperture* multiplied by the index of refraction for the medium in contact with the objective. How our friend Mr. Wilson can make this agree with his statement (quotation A) that it * has '*nothing to do with angle*' I must leave to him to reconcile. Hitherto I have been taught that the 'sine' has everything to do with its angle.

"It is alleged by Mr. Stephenson that the 'theoretical resolving power' is indicated by the calculation above described. Certainly it may be so, and I frankly admit that, as at present informed, I am unable to disprove it; but I look upon the statement not only with doubt and suspicion, but with a conviction that it will be very difficult to establish such a conclusion, and that at any rate it remains as yet in the category of things *not proven.*

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* [It will be seen, on referring to the original at p. 1091, that Mr. Shadbolt has (unintentionally we are sure) misquoted Mr. Wilson, who made no such statement. One of the factors in the expression of numerical aperture is the sine of half the *angle of aperture.*—Ed. J. R. M. S.]

"Of course, if it amuses anybody to adopt the views set forth because they may seem to glorify the objectives they possess by crediting them with excessive apertures, I see no reason against their indulging in a harmless eccentricity for their own satisfaction; but this does not alter the facts; and if they try to force others who understand perfectly that no 'aperture,' call it by what name you will, can possibly admit more than the whole of the emitted rays, they should not be surprised to find their assertions met with some not ill-natured raillery."

Mr. Crisp said that he should have much preferred that Mr. Shadbolt's paper were dealt with by some one from the general body of the Fellows; but, inasmuch as his censure for the dissemination of erroneous scientific views was directed both to the editorial conduct of the Journal and to the "authorities" of the Society, it had been thought better that he should deal with the matter. Having been suffering from somewhat severe indisposition which seemed to render it improbable that he should get to the meeting, he had committed what he had to say to paper, and must ask the indulgence of the Meeting to allow him to read from it.

"I quite accept Mr. Shadbolt's assurance that his raillery is not ill-natured, although, as will be seen in the sequel, he could not have chosen a more unfortunate occasion (so far as he personally is concerned) for the exercise of raillery of *any* kind. We have had oft-repeated demonstrations of the meaning of 'numerical aperture'; as full an explanation as could well be given has appeared in our 'Transactions,' a copy being sent to every Fellow; and yet we are presented with a paper to-night in which the author describes it as '*this mysterious numerical aperture of which we have no definition*'; asserts that those who employ the term '*have never, that he is aware, condescended to explain in definite terms what they mean by it*'; treats an incidental paper of Mr. Stephenson's in the second volume of the Journal, which he accidentally 'stumbled over,' as a '*simple expression of Mr. Stephenson's opinion*' which enables him (Mr. Shadbolt) to see that '*the mysterious numerical aperture is not an aperture at all, but a mere product of an arbitrary calculation*'; that '*as the best of the joke, it is actually based upon the much-maligned angular aperture,*' and that the '*table on the cover of the Journal is erroneous and misleading, and should at once be discontinued.*'

"Incredible as it may seem, it is nevertheless a fact, admitted by Mr. Shadbolt himself, that all this has been written—two months after the original note of November—without his having referred either to the papers of Mr. Zeiss* and Mr. Stephenson† in the first volume of the Journal, or to that of Professor Abbe‡ in the third (not yet a year old), which leaves no room for any 'mystery,' but gives the exact definition which it is asserted we are without, accompanied by full explanations.

"The Council were naturally placed in a position of difficulty as to this paper. Inasmuch as it was one presented to a scientific society on a scientific subject, it was not unreasonable to expect that before

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* See this Journal, i. (1878) p. 19. † Ib. p. 51. ‡ Ib. iii. (1880) p. 20.

the author censured particular views as 'misleading and erroneous' (with other similar expressions), he would at least have ascertained what those views were, especially as they were to be found in the Journal of the Society for the current year. As it was admitted that this had not been done, the Council would have been amply justified in declining to receive the paper.

"At the previous meeting, however, and in subsequent communications, Mr. Shadbolt (who was President of the Society in 1856) has expressed so strong a feeling that a desire existed on the part of some of the 'authorities' to suppress his views and to stifle discussion upon them, in the interest of 'numerical aperturists,' that the Council felt they had no alternative but to accede to his request and accept the paper, so that there could be no question as to his having had the fullest opportunity of recording his views.

"*Aperture and Angular Aperture.*—There are points in Mr. Shadbolt's paper with which not only I, but every other Fellow of the Society, will agree, and that is (1) that 'aperture' is properly defined as 'opening'; (2) that no lens can have an '*angular* aperture' in excess of 180°; and (3) that a dry lens can have as large an '*angular* aperture' as an immersion lens. If it is possible that any one has expressed a contrary opinion on these propositions, I may venture to say that he cannot have been a Fellow of this Society.

"The points on which we disagree, however, are (1) that there is no difference of aperture between dry and immersion lenses,—that no lens can have an aperture of any kind which exceeds that of 180° angular in air; and (2) that numerical aperture is 'misleading.'

"Mr. Shadbolt considers that he has demonstrated the latter points 'beyond dispute.' Now we know that an 'aperture controversy' was carried on for many years on this very question, and that those who originally supported the view now taken by Mr. Shadbolt ultimately admitted their error (or declared it was a mistake to suppose they ever held it). How is it that the opposite result was not arrived at if the whole matter can be explained in the extremely simple manner in which Mr. Shadbolt supposes it to be explained?

"The answer is, that there is one fundamental fallacy which underlies the whole of Mr. Shadbolt's paper, viz. the supposition that equal angles * in different media, as air and oil, are optically equivalent."

[*Unequal equivalent of Equal Angles in different Media—Apertures 'exceeding* 180° *in air.'*—Mr. Crisp then, by diagrams drawn on the black-board by Mr. Stewart, illustrated the phenomena of diffraction in the Microscope, showing by reference to Figs. 34 and 35, that (1) although the *angle* (at the object) was much larger in air than it is when the object is mounted in balsam, yet that the two angles were in reality *optically equivalent;* (2) that in the same way the 180° of a *dry* lens was the optical equivalent of the 82° of the *immersion* lens; and (3) that an angle in balsam greater than 82° *exceeds*

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* For convenience we have for the most part retained the use of the word "angle" throughout as applied to "pencils."

in optical effect the maximum air angle—the whole hemisphere—of 180°.*

Angles, therefore, of different degrees (as 180° in air and 82° in balsam) are shown to produce the same effects, i. e. take in the same rays, while angles of the same number of degrees produce (in air and in balsam) different effects; Mr. Crisp finally pointing out that the diffraction spectra were *one* † of the modes in which was demonstrated the *inequality of equal angles in media of different refractive indices;* that, for instance, 180° of radiation in air was *less* than that of 180° in water or oil.]

" It is the want of appreciation of this fact that lies at the root of the whole of the error into which Mr. Shadbolt has fallen in this question. His fundamental idea is that the *angle* is alone to be regarded; that the refractive index need not be taken into account; that equal angles must represent optical equality whether in air or oil. Hence he regards the table on the cover of the Journal as 'misleading' inasmuch as it shows 180° in oil and water to be something *more* than 180° in air; he supposes that it must therefore be intended to maintain that there can be an *angle* in excess of 180°; and he considers he has shown that 'no lens can have an aperture of any kind which exceeds that of 180° angular in air.'

" When it is recognized, however, that the optical effect of the 180° in air falls far short of that of the 180° in oil, all the seeming absurdities vanish.

" That Mr. Shadbolt's erroneous view on this point, and his failure to appreciate that the 180° of the dry lens is not the 'whole,' *is* the source of his difficulty, may be shown by the following quotations. In his original note p. 1090, he says :—

> " Let us suppose a dry lens of 170° of aperture to have " been placed in position to examine some transparent object " simply laid upon a slip of glass, which object is illuminated " from below; the lens would now receive and refract from " each luminous point a pencil of 170° [see Fig. 34].
>
> " But if that object were mounted in balsam, or other dense " medium, and protected as usual with a thin covering of glass, " the same dry objective could no longer refract *the* 170° *radiant* " *pencil of light*, because certain of the rays of *that pencil* would, " in their passage towards the lens, *fall on the upper surface of* " *the covering-glass*, at and beyond the critical angle, and would " therefore *find no exit;* the angular aperture of each pencil of " rays proceeding from the object, would therefore be limited to " an angle equal to double the critical angle for the covering- " glass employed [see Fig. 35].
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> " It now becomes apparent why an immersion objective can

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* These demonstrations have been repeatedly published, and are, therefore, omitted here. See the references collected in vol. ii. (1879) p. 651.

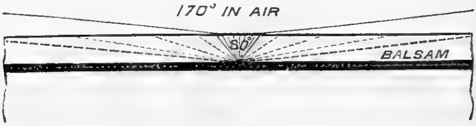
† From the subsequent discussion Mr. Shadbolt appeared to suppose that it was intended to convey that this could *only* be proved by reference to diffraction spectra. It need hardly be pointed out, however, that it is in principle a purely *dioptrical* matter, and is established by a simple *dioptrical demonstration* either with or without the Microscope.

" in suitable cases perform better than dry ones. With an appropriate fluid interposed the *critical angle* for glass becomes obliterated; and the pencil of rays, *whatever its aperture*, can pass direct to the posterior surface of the front lens, and there become refracted for effective use in forming an image; and this is where the immersion lens has the advantage; it can include as large a portion of the radiant pencils of light as the lens is constructed to admit, irrespective of the mounting of the object, but in no case can it reach, far less exceed, 180°."

Fig. 34.

"Fig. 34 represents the first position, as defined by Mr. Shadbolt—a pencil of 170° radiating from an uncovered object in *air*.

Fig. 35.



"Fig. 35 represents the second position,—the object in *balsam*, with a cover-glass, the pencil, at the object, being only 80° * (though expanding to 170° in air).

"Now if it is not recognized that the smaller angle of 80° in balsam of Fig. 35 is the exact optical equivalent of the larger angle of 170° in air of Fig. 34, it is easy to fall into Mr. Shadbolt's error and to look at the matter thus: In order to make the angle at the object in Fig. 35 equivalent *as an angle* to that of Fig. 34 (so that, as it is supposed, the *same things* may be discussed in both cases!), a pencil of 170° *in balsam* is taken as radiating from the object, as shown by the dotted lines. All of this pencil in excess of 82° (twice the critical angle) is reflected back from the cover-glass when a dry objective is used, but admitted with an immersion glass, and so follows inevitably the supposition that the value of an immersion lens is simply that it 'obliterates the critical angle for glass,' and so on.

"When once it is recognized, however, that the *large air* angle of Fig. 34 and the *small balsam* angle of Fig. 35 are optically *equivalent*, the whole difficulty vanishes. It is seen that there is no reduction of aperture with balsam-mounted objects (as was so long contended), and that in dealing with the balsam pencil of 170° shown by the dotted lines in Fig. 35, we have been dealing with one not merely equivalent to, but *very largely exceeding* the air pencil of 170° in Fig. 34.

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* This should strictly be slightly more to represent *exactly* the 170° in air.

"With a pencil in balsam of 82°, the dry lens takes up all that it is capable of taking up—that pencil is the equivalent of the 180° in air,—for the dry lens, that is *its whole;* for *it*, there can be no more than that whole. But the immersion lens of wide angle (i. e. exceeding 82° 'balsam angle') takes up a pencil largely in excess of the 82° which was the '*whole*' of the dry lens,—and its superior performance is seen to be wholly inadequately accounted for by the explanation given by Mr. Shadbolt.

"To take a second quotation from Mr. Shadbolt (*supra*, p. 157):—

> "If a dry lens be employed on a balsam-mounted object, a
> "portion of the radiant pencil is turned back by total reflection
> "at the air-surface of the covering-glass, when the incidence of
> "the rays exceeds the 'critical angle,' so that only a pencil
> "of not exceeding 81° 58′ can escape from out of the mounting
> "of the object to fall upon the front of the dry lens; *but that*
> "*does not affect the capacity of the lens, which is merely placed*
> "*in circumstances wherein its full powers cannot have play.*
>
> "It may be, and is, a very good reason for using an immer-
> "sion lens instead of a dry one, but it is monstrous to assert
> "that the latter has an 'aperture' exceeding that of 180° in air.
> "*The object is the thing at fault, and not the lens; the object has*
> "*been placed in a condition which prevents more than a pencil of*
> "81° 58′ *emanating from it.*"

"The same figures as I have used before illustrate this case also. So far from the dry lens being 'placed in circumstances wherein its full powers cannot have play,' its powers have the fullest play, and in the second case, quite as much as in the first, it receives its *whole*—the whole 180° of the radiation in air. As a dry lens it cannot utilize more.

("It will be seen that I have passed over two things: Mr. Shadbolt's omission to notice that the angle received by the front of the dry lens in Fig. 35 is 170° instead of being only 80°, and also that according to his demonstration an immersion lens shows exceptional superiority as regards aperture over a dry lens only in the case of the latter being used on objects mounted in balsam.* I do so because I wish to confine the discussion to the *one* point on which the whole matter turns.)

"If the erroneous assumption of the optical equivalence of equal angles in different media be granted, it is almost impossible for Mr. Shadbolt, or any one else, to avoid falling into the train of reasoning which appears in his paper, any more than it was possible for the old astronomers to avoid the erroneous explanations of the movements of the planets which were rendered necessary by the assumption that the earth was the centre of the system. When it is recognized that the equality or inequality depends, not on the angle only, but on the *refractive index of the medium* also—that the sun, and not the earth, is the centre—any such 'explanations' become unnecessary.

"So far, therefore, from Mr. Shadbolt having demonstrated beyond dispute, the incorrectness of the modern doctrine of aperture, he has given no demonstration that touches the question.

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* See also the original note at pp. 1090–1 of vol. iii.

"Nor can he or any one else ever succeed in doing so. It is as much a hopeless task—a demonstrable impossibility—as that of squaring the circle itself, whether looked at from a strictly mathematical or experimental point of view. The mathematical has been already given by Professor Abbe,* and the experiments which equally demonstrate it have been shown in this room time after time.

"The most striking of these is the application of an immersion lens, with 'balsam angle' exceeding 82°, to a dry-mounted and a balsam-mounted object successively. In the former case the lens acts as a dry lens of an aperture infinitely near 180°, and a bright circle is seen at the back of the objective having a diameter *less* than that of the posterior lens. With the balsam-mounted object the *whole* diameter of the back lens becomes brightly illuminated, and the surplus aperture of the objective in excess of 180° in air is manifest. If the difference between the diameters of the two bright circles is measured, it will be found to agree with that which should exist on theory.

"It has been the increased diameter of the back lens—so striking a feature in immersion objectives—that more than anything else has brought practical opticians in England to agree that there must be an actual increase in the 'aperture' or 'opening' of this class of objectives.

"*Mr. Shadbolt's Fig.* 33.—Mr. Shadbolt's reference to Professor Stokes's paper and the proposition which is illustrated by Fig. 33, is no less insufficient than that which I have dealt with. He cannot have worked out the effect of the diagram, or he would have seen that he had established the very proposition which he had designed the diagram to disprove! The demonstration requires, however, closer attention than can be given to it on an occasion like this, but it shall be printed in the Journal.† Meantime, however, I may point out that if Mr. Shadbolt will take the diagram to any working optician, he will find it at once pronounced not a practical construction for the purpose for which he proposes it.

"*Numerical* v. *Angular aperture.*—It is the same fundamental fallacy which has led Mr. Shadbolt into approving the sufficiency of the expression of angular aperture. For if it is erroneously assumed that the media have nothing to do with the matter, it does not seem absurd to say that '*angular aperture gives a very exact idea and measure of the proportion of a pencil of rays that a lens allows to pass*'; and that it '*has exactly the same value whether in a dry or an immersion lens, neither more nor less.*'

"It must be clear, however, from Mr. Shadbolt's paper itself that the expression *angular* aperture is erroneous and misleading, in that

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* It is intended to hang up in the library a copy of the diagram which illustrates the demonstration that no *dry* objective *can* have an aperture equal to that of an *immersion* objective with a "balsam angle" exceeding 82°.

† These Proceedings having run to nearly sixteen pages beyond the usual limit, obliges this to be postponed till the April Journal. It may, however, be stated shortly here, that when worked out, it is found that the Stokes objective and the Shadbolt objective magnify in the proportion of 7 to 5 approximately, so that the latter is *a lower power with the same back combination*, and therefore a *diminished aperture*, the actual figures being 51° instead of 66°.

it has misled him into assuming that equal angles denote optical equality, and that having 180° of radiation in air, that must be the *whole*, and that there can be nothing more. There is not one point of view, however, from which apertures can be compared quantitatively by means of the angles, because there is not one function in the performance of the Microscope in which twice the angle represents a double effect, or three times the angle a triple effect, except when the angles do not exceed a few degrees. Neither the quantity of light, nor the resolving power, nor any other performance connected with the aperture is increased in the ratio of 1 : 2 if the angle is increased from 60° to 120°.

"Thus, if a dry, a water-immersion, and a homogeneous-immersion objective are respectively denoted as of 60°, 53°, and 48° angular aperture, a further calculation is necessary for the appreciation of their true relations *inter se.*

"Aperture is only correctly defined when the *various refractive indices of the media* are taken into account as one of the factors, and, further, as two objectives with the *same medium* cannot be compared by the degrees, it is readily seen that the sine and not the number of the degrees must be the other factor, and the complete formula becomes $n \sin w = a$, where n is the refractive index of the medium, w the sine of half the angle, and a the numerical aperture. Angular aperture was an insufficient expression when only dry objectives existed, and it has continued to be used since the introduction of water- and oil-immersion objectives simply from force of habit. If, however, all three classes of objectives had always co-existed, is it conceivable that any one would have established a notation *which denoted things as the same when they were different* (60° *in air and* 60° *in oil*), *and different when they were the same* (180° *in air and* 82° *in oil*)?

"Although it has already been so fully done by Professor Abbe in the paper to which I have already referred, as well as in the further paper now awaiting publication,* I may summarize (entirely from these papers) the advantages of the expression of *numerical* over angular aperture.

"1st. *It introduces an absolute measure of aperture, the unity of which is based on a fundamental phenomenon.* This is the radiation of a luminous point in a medium of the refractive index = 1, the rays in which are embraced by an entire hemisphere. The capacity of an objective for collecting the total hemisphere *in air* is the *unit of aperture* with which, by the value of a, every individual aperture may be compared.

"2nd. *It is the only one which affords a correct idea of the true relation of different apertures in the same medium;* whilst, on the contrary, the angles inevitably lead to a false conception of this relation.

"3rd. *It is the only way in which apertures pertaining to different working media can be compared.* A comparison by the angles is

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* The paper of Professor Abbe, which the Council have decided to publish in a separate volume when complete, constitutes the most exhaustive, and indeed the only, scientific exposition of the function of aperture in microscopical vision which has been attempted in this or any other country.

simply impossible unless by reducing them to a common medium, which (as in the 'balsam angle' of a dry objective) has no actual connection with the intended action of the lens. The definition of a reveals at once the unequal equivalent of equal angles in different media. The aperture indicated by an angle of say 120° in a medium like balsam or crown glass exceeds the aperture indicated by the same angle in air in the exact ratio of the refractive indices 1·5 and 1·0. The greater value of a (in the formula $n \sin w = a$) which appertains to the same angular aperture in a more highly refractive medium indicates numerically the increase in the effective rays which is secured for the delineation of the image. Thus the superiority of immersion objectives in all those functions which depend on aperture is directly manifested by the increased value of a obtained by the immersion method.*

"Instead of the three objectives being denoted by 60°, 53°, and 48° *angular* aperture (a descending scale), the *numerical* expression gives ·50, ·60, and ·62 (an ascending scale), and the comparison of their true relations is at once made.

"*Conclusion.*—The want of appreciation of the aperture question in this country grievously retarded our progress in optical matters. Years ago, when Continental workers were revelling in the superior capacities of immersion objectives, English microscopists and opticians persistently refused to countenance them: 'the aperture was obviously cut down so much by the mounting in balsam'; and again, although the use of oil had been suggested by Amici in 1844 and by Oberhauser in 1845, and re-suggested by Wenham in 1855 and 1870, yet oil-immersion lenses were for all these years (and down to 1878) utterly ignored as without any practical utility, and the principle of homogeneous immersion was at that time entirely missed through the persistence of the fallacy that the 'aperture was cut down.'

"I may take this opportunity of removing some misapprehension which has existed as to the resolution of the Council that the controversy on the aperture question should be 'closed.'† It is not meant that the subject is to be considered as tabooed by the Society, but simply that when a question, at first doubtful and little understood, has at length by discussion and experiment been demonstrated, the time has come when it is not possible for a Society to occupy the time of its principal meetings by further discussion of the general question. If, after that, any individual Fellow desires to understand and discuss the grounds for the belief, that obviously can only be done by communications *inter se* or at some of the less formal meetings. It is for this purpose that we meet weekly in the Library, and on these occasions, so far from desiring to stifle discussion on any question, the Secretaries and any other Fellows present are always pleased to give any assistance that they can on any desired subject, whether it relates to the circulation of the blood, or the law of refraction, or any more difficult topics.

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* See also Professor Abbe's demonstration as to how all the principal functions of microscopical vision (the illuminating power of an objective, the depth of focus, and the resolving power) depend upon the expression of a.—Vol. iii. (1880) p. 26.

† See this Journal, ii. (1879) p. 345.

"If Mr. Shadbolt had been as right in his views as he has turned out to be wrong, I venture to think it will be agreed that raillery (even if good-natured) was a mistaken course to adopt, and in fact revives the objectionable features of the old aperture controversy which we hoped we had at last got rid of. I don't complain of being called a 'harmless eccentric,' nor of being told that I am trying to persuade the readers of the Journal of what I know (or ought to know) instinctively is not true; and so far from desiring to be above criticism, I should be glad to have more criticism than I at present get, that I might be better able to meet the wishes of the Fellows at large; but I think it may be fairly required that censure shall not be persistently pressed, except as *following, and not preceding, the understanding of the subject in respect of which the censure is bestowed.* Nelson applying his blind eye to the telescope directed upon his admiral's signal, and declaring that he 'could not make it out,' may have been an excellent action at its proper time and place, but cannot usefully be transferred to so very different a field as we have to deal with." *

The Discussion, of which the following is a summary, subsequently took place:—

Mr. T. Powell said that, speaking simply as an optician, he was bound to say Mr. Shadbolt's Fig. 33 did not represent a practical construction.

Mr. Ingpen said that he entirely agreed with Mr. Crisp upon the general question. As he had originally introduced the apertometer to the Society, on the occasion when he read Mr. Zeiss's paper, he should mention that that paper showed what was meant by "numerical aperture," as well as the way in which the apertometer was applied. All, however, that he was concerned about in the present instance was to point out the explicit way in which the principle of the apertometer had been explained to the Fellows. The table to which Mr. Shadbolt objected was simply a table of sines. If it was carried out beyond 180° it was still a table of sines, but in

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* We were asked subsequently to the meeting whether we had taken Mr. Shadbolt's view to be that radiation in air and in oil were the same thing. We could only reply that that was assuredly so (see *ante*, pp. 150 and 155). Hence alone the necessity of demonstrating the "unequal equivalent of equal angles in different media." We find it, nevertheless, difficult to understand how this fact can seem to be paradoxical, when no one thinks it strange that a bell with the same stroke will yet give out an increased sound in different media.

This fundamental fact is, moreover, not only the answer to Mr. Shadbolt, but is the *key to the whole of that puzzle which was known as the "aperture question."* Not being recognized, certain of the disputants wandered up and down for years in the most extraordinary maze that a scientific subject was ever entangled in. One of the most amusing incidents of the controversy was the way in which one side puzzled not merely the *opposite* side, but *themselves* also, by such a "difficulty" as the application of a small hemisphere of glass to the object. This, of course, increased the amplification in the proportion of 3 : 2, so that there was a higher power with the same back-combination and the same diameter of the emergent pencil as before, and therefore increase of the aperture, but the discussion went on as if there was no such amplification, or that if it existed it had no influence on the problem under discussion!

that case the sine was multiplied by 1·33 if for water; or going higher still, by 1·52 for crown glass. Had Mr. Shadbolt ever seen the apertometer? If not, would he like to see it? There was one in the room which had been brought for the purpose.

Mr. Shadbolt said he did not desire to see it; he had simply disputed the idea that any aperture could possibly be greater than a whole.

Dr. Edmunds said he thought that much of the dispute on this question was a question of nomenclature. A luminous object in the focus of an objective could be taken in three conditions. Firstly, as in air and uncovered; secondly, as optically connected with the lens-face by a homogeneous medium, such as oil or balsam; thirdly, as set in balsam under a cover-glass with a stratum of air above.

In the first case a plane-fronted air lens may receive a pencil of rays nearly a complete hemisphere. If the distance be such that a pencil of 140° strikes the lens face, and the objective be capable of reducing into image the whole extent of this pencil, the objective is an air lens of 140° angle of aperture. In the second case, if the back surfaces be so increased in depth and power as to replace the action of the lens-face (abolished by the homogeneous immersion), we shall have a homogeneous-immersion objective of 140° angle of aperture. The image now given will be much brighter than the first, but why? Not because the angle of aperture has been augmented, but because the amount of light transmitted within the same angular range has been vastly increased by abolishing the *reflection* as well as the refraction of the lens-face, and therefore the whole pencil of 140° has actually entered the lens front. In the third case we use the lens corrected for air as at first. Here the pencil of 140° is divided into five portions, of which four are mechanically diverted, and one only enters the lens-face. (1) That portion of the pencil outside the angle of 41° is wholly reflected backwards. (2) That portion of the pencil inside the angle of 41° is split into two portions, of which one is reflected backwards and the other emerges from the surface of the cover-glass. (3) The 82° portion emerging into air is refracted so as to be expanded into a pencil of 180°, of which only the central 140° reach the lens. (4) This 140° pencil is split by the lens-face, one portion of the pencil is reflected, and only the remaining portion enters the lens. Thus the light emitted from an object in air, uncovered, is received upon the face of an air lens and utilized to the full range of its angular aperture. The same object set in balsam under a cover-glass is so environed that only a small portion of its pencil is allowed to reach the face of an air lens. The beauty of the image given by the homogeneous lens depends upon the quality and intensity of the pencil which enters the lens, and not upon its increased range of angular aperture.

Mr. Crisp said that apart from Dr. Edmunds' demonstration that there could be no angle of aperture exceeding 180° (which no one had ever attempted to dispute), the mistakes into which he had fallen were all traceable to the same fundamental error (by no means a mere question of nomenclature) as that which had misled Mr. Shadbolt, though expressed in a different form.

In the first place, he reproduced the view which was current when immersion objectives were first introduced, and explained the "vast increase" of light transmitted by the homogeneous-immersion objective as compared with a dry objective of 140°, as being due to the "abolition of the *reflection* and refraction of the lens face." Now the *increase* of light in the immersion-objective was as $1 : (1 \cdot 5)^2$, or as $1 : 2\frac{1}{4}$, i. e. an increase of 125 per cent. But the *loss* by reflection in the case of the dry lens was only 10 or 12 per cent., so that there was an enormous surplus left unaccounted for, and the explanation now given was wholly untenable.

In the second place, Dr. Edmunds treated the object mounted in balsam as being "so environed that only a *small* portion of its pencil is allowed to reach the face of an air lens." This is the old fallacy —pure and simple—that there is a reduction of aperture on balsam-mounted objects. So far, however, from the "environment" of the object being an impediment, the dry lens receives the *whole* pencil in that case as much as it does when the object is in air and uncovered.

Mr. J. Mayall, jun., wished to know from Mr. Shadbolt, whether he maintained that no immersion objective could utilize rays from a radiant in air that were not effective when an ordinary dry objective was used?

Mr. Shadbolt said that was not his point—his paper was to demonstrate that not only a dry lens, but that no lens of any kind could have an aperture of any kind that exceeded that of 180° angular in air. No angle greater than the whole of the rays emitted from an object could by any possibility be got.

Mr. Mayall said that what had been demonstrated over and over again was that, under suitable conditions, an immersion lens may utilize image-rays that cannot be utilized by any dry lens. When the angle of aperture of the highest-angled dry lens, approaching 180° air angle, was measured in the body of an ordinary crown glass semi-cylinder or hemisphere, the reading was always well within 82°, that is to say, twice the "critical" angle. But some of the recent homogeneous-immersion lenses gave a reading of upwards of 140°. How were we to designate apertures such as this latter? If a dry lens with a plane front was limited to 82° in glass (which is the equivalent of the maximum air angle of 180°), whilst an immersion lens gave 140° in glass, the aperture of the latter was greater than the equivalent of the maximum air aperture. Some term must be found to meet the case, and Professor Abbe had accordingly suggested "numerical" aperture, which enabled a comparison of apertures in all media to be made by simple inspection. If Mr. Shadbolt could suggest a better plan of universal notation for apertures, doubtless it would readily find supporters. To take the interior angle (in the front lens) led, as Professor Abbe had shown,* to the same absurd results as "angle of aperture" itself.

Mr. Shadbolt said he thought the case between Mr. Mayall and himself to be that Mr. Mayall assumed that an immersion lens

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* See this Journal, iii. (1880) p. 24.

resolved better because of its larger angular aperture, whilst he said that it did so in spite of its aperture. He wished again to repeat that what he desired to express was that if a dry lens of 180° were possible, then it would certainly include the whole of the rays proceeding from any radiant point, and inasmuch as the whole of the rays were included in the 180°, they could not get a lens which would include more than the whole.

Mr. Stewart made some remarks on the mode in which the diffraction spectra demonstrated the larger aperture of homogeneous-immersion lenses.

The following Papers and Notes were taken as read, there not being time to discuss them:—

Professor E. Abbe:—On the true conditions of Stereoscopic and Pseudoscopic Effect in Microscopical Vision.

Mr. J. C. Douglas:—(1) Silver films for instruments of the Camera Lucida class. (2) Simple device for handling thin covers (see p. 140). Mounting clip (see p. 141).

Dr. Herpell:—On preserving Fungi (see p. 136).

Dr. Maddox:—Note on the Aeroconiscope (see p. 134).

Mr. J. Mayall, jun.:—High Amplifications (see p. 127).

Mr. Mereschkowsky:—The Movements of Diatoms (see p. 102).

Mr. Nelson:—Centering nose-piece as a substage (see p. 125).

Dr. Royston-Pigott:—A general and transfer Finder (see p. 115).

Mr. A. W. Waters:—Dry mounts for the Microscope (see p. 138).

(Mr. A. D. Michael's paper "On a species of Acarus believed to be unrecorded" was postponed until March.)

The following Instruments, Objects, &c., were exhibited:—

Mr. Coppock:—A Microscope constructed in 1878, with the same fine adjustment as that subsequently patented by Mr. Bulloch and described and figured in vol. iii. (1880) p. 1073.

Mr. Crisp:—(1) Bulloch's Histological Microscope (see Journal, vol. iii. (1880) p. 1079). (2) Bateman's Microscope. (3) Browning's Portable Rotating Microscope. (4) Atwood's Rubber Cells (see Journal, vol. iii. (1880) p. 1041).

Mr. Curties:—Gundlach's $\frac{1}{8}$ Homogeneous-immersion Objective (see p. 120).

Dr. Royston-Pigott:—General and transfer Finder (see p. 115).

New Fellows:—The following were elected *Ordinary Fellows*:—Messrs. Richard Andrews, the Hon. Jacob D. Cox, Edward J. E. Creese, John C. Foran, John J. Hunter, John W. Reed, G. J. Smith, and C. M. Vorce.

WALTER W. REEVES,
Assist.-Secretary.

The Journal will in future be published on the second Wednesday of February,
April, June, August, October, and December.

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APRIL, 1881.

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JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY;

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS,

AND A SUMMARY OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(Principally Invertebrata and Cryptogamia),

MICROSCOPY, &c.

Edited by
FRANK CRISP, LL.B., B.A., F.L.S.,
One of the Secretaries of the Society;

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE, AND OF

A. W. BENNETT, M.A., B.Sc.,
Lecturer on Botany at St. Thomas's Hospital,

F. JEFFREY BELL, M.A.,
Professor of Comparative Anatomy in King's College,

S. O. RIDLEY, B.A., *of the British Museum*, AND JOHN MAYALL, JUN.,
FELLOWS OF THE SOCIETY.

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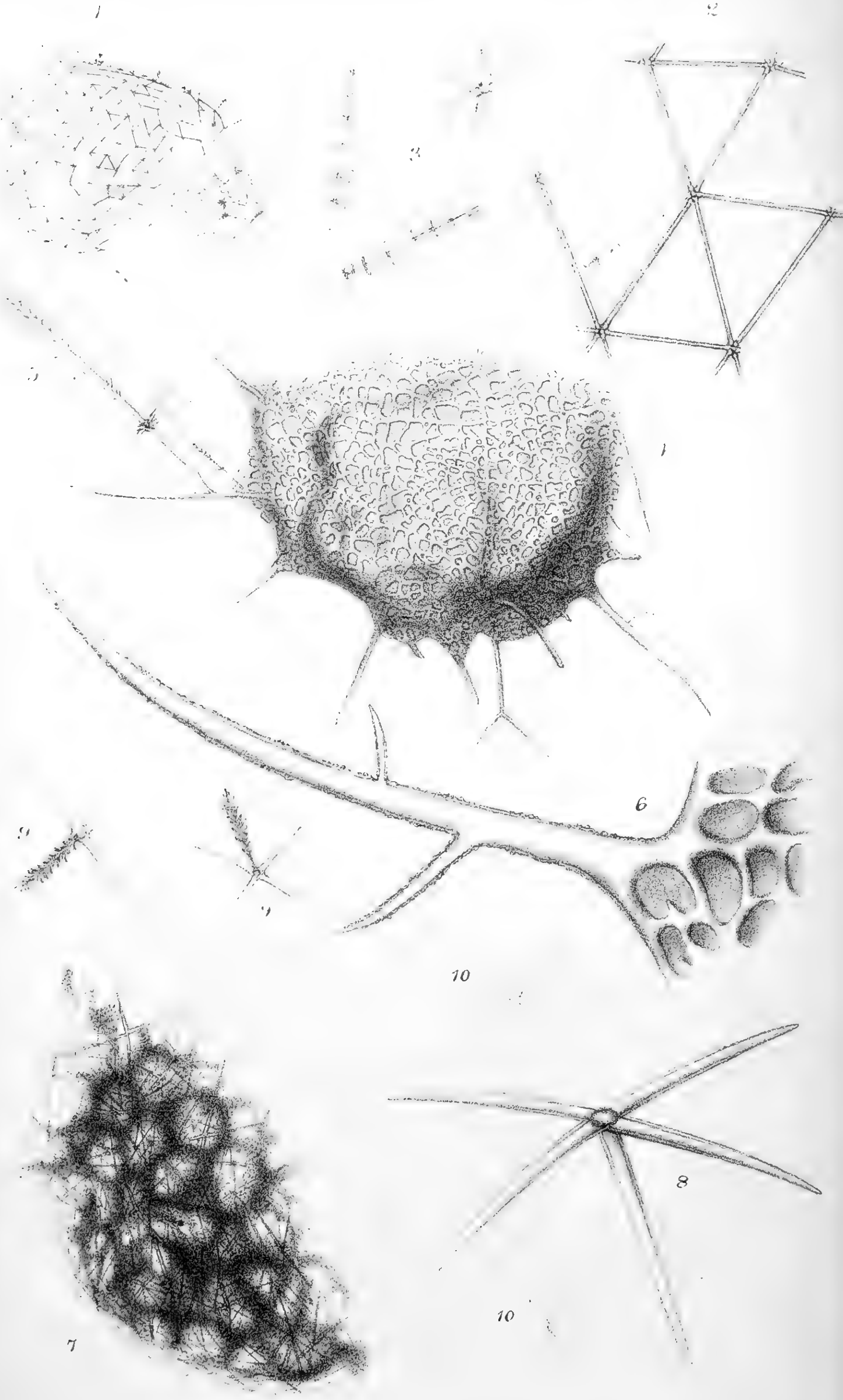

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Radiolaria & Microspongida

JOURNAL

OF THE

ROYAL MICROSCOPICAL SOCIETY.

APRIL 1881.

TRANSACTIONS OF THE SOCIETY.

II.—*On a Radiolarian and some Microspongida from considerable depths in the Atlantic Ocean.* By Professor P. MARTIN DUNCAN, M.B. (Lond.), F.R.S., &c., Vice-Pres. R.M.S.

(*Read 12th January*, 1881.)

PLATE III.

IN cleaning some specimens of recent corals, which had been dredged up during the expedition of H.M.S. 'Porcupine,' and others which had been given to me by the late Count de Pourtalès, from the Caribbean Sea, I found a great number of minute sponge-like bodies. Some few were entangled in the consolidated ooze with which the cups of some dead corals were filled, and the rest were fixed to different parts of all kinds of living and dead corals, many being parasitic within.

The corals had been subjected to a rough washing before they came to me, or had had to submit to one during their passage upwards in the dredge through many hundreds of fathoms of sea-water; but they had not been placed in spirit, and they had dried. On removing a few of the specimens of the minute bodies from the ooze of the cups, a matter of great difficulty, some were broken; but three were disentangled without much injury. They were so small that it was desirable not to place them under the action of cleaning media, but to transfer them at once to Canada balsam in a cell.

On examining these little bodies, I was struck, not only with their great beauty, but also with the Radiolarian appearance of two of them. The third was indubitably a true hexactinellid sponge of the Lyssakine division.

The position in classification of one of the specimens with a continuous siliceous skeleton, would appear to be in the family

Aulosphæridæ (Haeckel), amongst the Radiolaria, but its whorled hexradial spines, and the excessive delicacy of the skeleton, are suggestive of the derm of some sponge. Nevertheless, the figure given by Haeckel of *Aulosphæra elegantissima* Haeck., on plates x. and xi. of 'Die Radiolarien,' decides the question.

The second body with Radiolarian appearance in the continuous skeleton, has a distinct hexactinellid brush-spicule in the sarcode adhering to it, and the resemblance of the areolation to that of some of the Dictyonine Hexactinellid sponges is perfect. Nevertheless, there are doubts in my mind whether it is one of the Spongida; for unless the oscule has been turned in and the sides crushed down and more or less obscured by sarcode, during the process of mounting, there is not one at all. The brush-spicule and some elongate ones are, however, very difficult to account for on the plea of being accidentally adherent.

I. The following are the characters of the *Aulosphæra*:—The body is irregularly ovoid in shape and closed. It consists of one layer of continuous spiculæ, forming a network of hexagons, and the whole of the included space is unoccupied by any skeletal structure. The hexagons forming the meshes are equal in size, have a very regular direction in longitudinal series parallel with the long axis of the body. Each hexagon consists of six equal spiculæ which meet centrally, and of six other spiculæ which join their eccentric ends and form the outline. The spiculæ are very slender, straight, equal in thickness, cylindrical, and hollow; and the interspaces are large and equal. The geometrical arrangement is therefore exceedingly perfect; and as similar hexagons in contact at their outlines permit of their radii and bases being confused, the eye notes that the spiculæ of one hexagon may be said to form parts of the neighbouring ones. No swelling occurs at the junction of the spiculæ, but wherever any meet, there projects a spicule perpendicularly, and it is remarkable in form. The body is thus hirsute with projecting spiculæ, and they are extremely slender, long, and are marked by nearly equidistant whorls, from seven to nine in number, of four radiating, minute, and slightly recurved spiculæ. Either the projecting whorled spicule ends with a whorl, or it is produced as a linear spine. The length of one of these spiculæ is nearly equal to that of one of the skeletal spiculæ, but they are much more slender than the hollow skeletal parts. Where the base of the projecting spicule meets the ends of the skeletal spiculæ, these last are hollowed, as it were, for its inception. Some of these remarkable spiculæ are in place in the specimen, others have been broken off, and many have been injured or are rudimentary; but there are many of the type described. The largest are ·063 mm. in length.

The length of the whole body is nearly 2 mm., its height 1·5 mm., and the breadth of each hexagonal system is ·125 mm.

Locality: from the calice of a dead piece of *Lophohelia exigua* Pourt., in the Caribbean Sea. Depth, 280 fathoms.

The great slenderness of the meshes, the extreme delicacy of the projecting spiculæ, and the presence on them of from seven to nine equidistant whorls of four small, slightly recurved spines, distinguish this form from the species described by Haeckel under the name of *Aulosphæra elegantissima.*

I have named the new species *Aulosphæra Pourtalesi.*

(Description of the illustrations of *Aulosphæra Pourtalesi* Dunc., Plate III.:—

Fig. 1. The body, magnified 30 diameters.
„ 2. A portion, magnified 150 diameters.
„ 3. Some whorled spiculæ, magnified 300 diameters.)

II. The second form, with some Radiolarian aspects, but with the structural elements of a sponge, was taken from the calice of a dead coral which had been dredged from off the floor of the Atlantic, near the coast of Portugal, in very deep water.

The body is globular, and the oscule is not visible. The surface of the body consists of a layer of continuous siliceous network, without visible spiculæ or spicular canals, and of a more deeply rooted network in one or two places. Otherwise, there is no structure within the thin film of the outside of the body. The siliceous meshes of the network are semi-transparent, rather flat, and very irregular in their breadth, direction, and in the size of their contained or environed spaces. There is no granulation to this skeleton, and there are five kinds of accessory spiculæ attached to and arising from it. Firstly, long and more or less cylindro-conical, attenuate, curved spiculæ, with curved processes coming off here and there at irregular distances, the curving being from the body as a rule, but not invariably. These large spiculæ are not equally cylindrical, and their edges are more or less wavy; they are thickest at the body, and become more or less slender soon, and terminate rather gradually in a point. They have no visible central canal, and they arise from the junction and prolongation outwards of several neighbouring parts of the siliceous continuous skeleton. As there are several of these large spiculæ thus arising from several parts of the outside of the body, they give a very definite aspect to it. They are embedded in sarcode, and probably had to do with retaining the body in its oozy resting-place.

Secondly, shorter spiculæ arising from one bar of the continuous network, and which have rather long, slightly enlarged at the base, but very attenuate shafts. These shafts give origin to two or more curved processes, some of which are finely granulo-punctate or very minutely spinulate. They stick out boldly from the body.

Thirdly, long, slender, curved spiculæ, with lateral processes or slight hooks. These arise from the edges of a mesh, and cross over the interspace and one or more meshes, being placed on the body and parallel to its surface.

Fourthly, slender, short spiculæ, with a cylindrical base and a rapidly attenuating stem and a fine point. These arise from the outer part of the calcareous mesh.

Lastly, small processes, curved or straight, which project from the siliceous mesh into the interspace. They differ much in length, and some are long and have a side projection on them.

Much of the sarcode of the exterior of the sponge remains, and there are some dermal spiculæ here and there, but only three forms are recognizable.

Firstly, a four-limbed spicule has its opposite limbs placed along one of the longer spicules of the sponge, and where they cross at right angles there is a prominent boss.

Secondly, a well-developed hexactinellid spicule, ending in a long and well-developed aciculate brush, and being prolonged in the opposite direction into an attenuate needle.

Thirdly, some very long, linear, attenuate spiculæ, in lateral apposition.

The reticulation of the body is very remarkable, and the roots, so to speak, of the great cylindrical spiculæ pass on the body as broader meshes than those which arise from them, and form a network irregular in the size of the spaces, but somewhat regular in its direction.

The length of the body is 2 mm.

Coast of Portugal; depth, 1095 fathoms.

This might be considered a perfect germ of a Dictyonine Hexactinellid. The form may be a young one, but nevertheless the spiculæ are without canals. It is not a young Aphrocallistes, Euplectella, or Farrea, and in its irregularity of mesh it approaches Dactylocalyx of Schmidt, not Bowerbank. But the details of the ornamentation, and the nature of the principal body-spiculæ, distinguish the new form.

If it is a sponge, it falls into the Dictyonine division of the Hexactinellids. But if the dermal spiculæ are accidental, and if there is no oscule, the form will come under the Radiolaria. I propose to leave the question of the zoological position open.

(Illustrations of the species:—

Fig. 4. The body, magnified 30 diameters.
„ 5. The brush-spicule, magnified.
„ 6. The long spicule, magnified.)

III. The third specimen was also derived from the calice of a coral which was crowded with Globigerinæ, from the North Atlantic.

It belongs to the Hexactinellids with a discontinuous skeleton, and is a much more complicated body than the others, resembling in its body-structure, but not in the long spiculate arrangement, a full-grown Holtenia.

Description:—

The body is not quite 3 mm. in breadth, and is less in height; it is broadly cup-shaped, with a large oscule whose limits are ill defined. There are two portions to be considered: the main framework, and the outer dermal framework.

The main framework is composed of a series of large quinqueradiate spiculæ, four of the radii being on one plane—that of the surface of the sponge—and the other at right angles, and penetrating inwards towards the centre. The outer radii are faintly curved, are equal, and taper to their extremities.

Where they join to unite with the long attenuate inner part, there is scarcely any swelling, or none at all externally. The rays of one of these four-armed spiculæ nearly reach to the centres of their neighbours, but there is never perfect and solid contact. These primary spiculæ are not all of the same size, the largest being nearly twice the size of the others. These smaller ones are overlapped by the others. Below the trellis-work formed by the curved radii, is the thickness of the sponge-body, and it is composed of the long, needle-shaped inner limbs of the primary spiculæ, and amongst them are hexradiate spicules with the junction of the cross-pieces smaller, and the radii are shorter than the vertical portion. Besides, there are long, slender, slightly curved, attenuate pointed spiculæ, without hooks or ornamentation.

These three kinds of spiculæ are especially those of the body, and there are numerous long, linear, delicate spiculæ, plain at the ends, which come from the body-mass and pass out through the lattice-work of the great quinqueradiate spiculæ, and bend over the framework and enter partly into the composition of the derm.

The spiculæ of the derm are numerous, and are of six kinds:—

Small quinqueradiate spiculæ, whose four limbs rest partly on the outer part of the primary spicules of the body, and the fifth passes inwards.

Small quadriradiate spiculæ, with their attenuate extremities minutely punctate.

Small hexradiate spiculæ, with minutely punctate extremities.

Small feather spiculæ, the feather being excessively slender, yet sharply aculeate, in irregular whorls; and the four other equal limbs being in the form of a cross, resting in the derm.

Small hexactinellid spiculæ, with feathered ends like the last.

Long, slender, attenuate, linear spiculæ, some continued within the body, others free and curved about the derm.

The projections from the surface are the numerous minute feathered portions of the derm spiculæ, and the ends of some of the long, silky, linear spiculæ.

Most of the smaller spiculæ are punctate, as it were, at the surface, near their sharp ends, and in none could I detect a canal. Some of the quadriradiate kind have a knob in place of the fifth limb. Neither hamate spiculæ nor amphidisci exist.

This wonderfully complicated little hexactinellid sponge has a broad osculum, which in the specimen described, is in contact with the lower glass of the confining cell. The spicular elements are more delicate there.

It happened that in removing this sponge—a matter of great delicacy—some extraneous sponge-matter was accidentally included in the osculum. Fortunately, it belonged to a continuous-fibered hexactinellid, so it can be separated in the description from the Lyssakine form which is now under consideration.

Locality: North Atlantic, out of a calice of a *Lophohelia*, in deep water.

The little form is characterized by the numerous primary spiculæ, by the closeness of the meshes formed by them and those slightly smaller, and by the presence of hexradiate spiculæ and long, linear, curved spiculæ in the body. By the presence of small hexradiates, quadriradiates, feathered hexradiates, and long silky fibres in the derm. By the occasional projection through the meshes, of the ends of linear, attenuate spiculæ; and by the absence of a beard, roots, amphidisci, and hamate spiculæ.

If these characters are compared with those of some minute *Holtenia Carpenteri* which were dredged by H.M.S. 'Porcupine,' and carefully described by Sir Wyville Thomson, F.R.S., in the 'Phil. Trans.,' 1869, plate lxxi., the distinctness of the forms will become apparent. The following is an extract from the essay on *Holtenia*, p. 717:—

"During the deep-sea exploring cruise of H.M.S. 'Porcupine,' the dredge brought up from the depth of 725 fathoms, off the mouth of the English Channel, several young specimens of *Holtenia Carpenteri* W. T., with a sponge-body from 2 to 200 mm. in length. The youngest specimens seemed only to have passed out of the condition of gemmules. The contour of these young sponges is more elongated and pyriform than that of mature examples. The external wall consists of a single series of quinqueradiate spicules, much more regular in form than those of the larger sponges. The four secondary branches decussate nearly at right angles, and the fifth branch is quite straight, and plunges into the sponge nearly vertically. During the growth of the sponge, the spicules, while enlarging greatly, become distorted and irregular in the distribution of their rays; the smaller spicules of the sponge-body are likewise more regular, and a few examples were met with of the very regular hexradiate spicule, a form which is very abundant in *Hyalonema*. In the youngest sponges, the stellate arrangement of the outer membrane is not yet perceptible; the surface is merely divided by the spreading rays of single spicules into rudely square meshes. The osculum is distinct from the first.

"The feathered spicules are seen along the shafts and branches of the spicules of the outer and oscular walls. All have a beard of a single pencil of long spicules passing out through one of the meshes of the outer wall, in the centre of the narrow inferior end of the sponge, opposite the crown of the osculum. The fascicle consists of from twenty to thirty of the long, simple spiculæ, and four or five of the bihamate spined spicules. At this stage, it is difficult to distinguish young *Holteniæ* from young *Hyalonemæ*."

Other small *Holteniæ* have been described by Oscar Schmidt;* one, *Holtenia Pourtalesi* Schmidt, from Florida, 154–324 fathoms, and *Holtenia saccus* Schmidt, from the same locality. Both are without the pencil of long, axial, glossy spicules, but have a tolerably wide oscular opening, and their spiculæ differ from those of the new form.

The question, Is this microscopic sponge an adult? is not very readily answered. Were the body less complicated, and less elaborately stellate, there would be no difficulty in replying that it is not, but it is a perfect little sponge in all its parts. As there is some uncertainty about the stage of growth which the sponge presents, although it is advanced far beyond the gemmule stage, I do not propose to associate it with any genus or species, but simply to record it as a minute, highly-developed Hexactinellid of the Lyssakine division.

(Description of the illustrations of the Lyssakine Hexactinellid:—

Fig. 7. The sponge, magnified 50 times.
„ 8. The primary spicule, magnified.
„ 9. The feathered spicule, magnified.
„ 10. Small hexactinellid spiculæ, magnified.)

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* 'Grundzüge einer Spong-fauna des Atlan.-Gebietes,' Leipzig, 1870, pp. 14, 15.

III.—*The President's Address.* By LIONEL S. BEALE, F.R.S.

(*Annual Meeting, 9th February,* 1881.)

THE year 1880 has been with us one of prosperity and progress. Including Honorary Fellows and those elected Ex-officio Fellows, we now number 610. During the past two years 105 new Fellows have been elected. A glance through the numbers of our 'Journal' will convince any one of our increasing activity and advancing work. Valuable as well as highly interesting original memoirs, numerous new instruments, and multitudes of preparations shown at our meetings afford unmistakable evidence of the activity and energy of many of our Fellows; while the increased numbers attending our meetings during the past year attest the unflagging interest taken by the Fellows in every branch of microscopical work which it is the aim of our Society to encourage and promote.

Since the last anniversary we have lost some of our members by death. Among these we have to regret the loss of an original Fellow and former President, Professor Thomas Bell, F.R.S., the first Professor of Zoology in King's College, and the author of well-known books,—'British Quadrupeds,' and 'British Reptiles,' as well as other works. He will long be remembered as a distinguished naturalist and as the successor of the celebrated Gilbert White of Selborne.

Professor David Thomas Ansted, M.A., F.R.S., formerly Professor of Geology in King's College, was an enthusiastic worker in his department of science, and author of many treatises and valuable memoirs on subjects connected with Geology and Physical Geography. He became a Fellow of our Society as far back as 1845.

Robert Ceely, F.R.C.S., of Aylesbury, was elected a Fellow in 1852, and though I am not aware he wrote any papers on strictly microscopical subjects, few were more zealous and active in the study of minute changes going on in disease. During a long life he devoted himself to investigations in connection with vaccination, and wrote some most valuable memoirs full of the results of careful investigation and original thought. I was fortunate in becoming acquainted with Mr. Ceely early in my career, and have often been astonished at the activity and freshness of his mind. He skilfully performed delicate surgical operations when he had reached fourscore years. At the age of eighty-three he was still active and enthusiastic, and up to his death at that advanced age was performing the duties of a country surgeon in large practice. He was one of the most unselfish of men, and was greatly respected and beloved by all who knew him.

John Thomas Redmayne, of Bolton, L.R.C.P. Edin., M.R.C.S., died in October last at the age of thirty-three. One who was well acquainted with him says that he was a most skilful microscopist, and devotedly fond of the work. He was also an excellent microphotographer. The Bolton Microscopical Society was founded by Mr. Redmayne, and, as his friend remarks, had he lived he would undoubtedly have taken a high place in the scientific world.

The Society has also lost by death Mr. Frederick Bunting, Mr. M. C. Hardy, Colonel Hennell, and the Rev. James Clifton Ward, F.G.S.

Dr. Henry E. Fripp, of Clifton, as President of the Bristol Naturalists' Society, was an Ex-officio Fellow of the Royal Microscopical Society. He was well known as a physician in Bristol, and he formerly lectured on physiology at the Medical School. He contributed some memoirs to our Society, and several papers to the Bristol Naturalists' Society. His papers "On the Theory of Illuminating Apparatus," published at intervals during the past two years in our 'Transactions,' are of interest and value.

As it is usual on this occasion for the President to deliver an address, I venture to offer for your consideration this evening some suggestions in connection with a subject which in one or other of its aspects must needs be of great interest to every one who wishes to learn all he can about the wonderful changes which continually go on in all living things, some being within and some beyond the present limit of scientific investigation; and though I shall express some views with which perhaps many here will not agree, I trust my remarks may kindle interest and encourage discussion, rather than offend. Where wrong I shall be glad to be corrected, but I claim permission to speak freely what I think, and liberty to advance my conclusions, which, though not at present very popular, may yet be worthy of your consideration.

THE MICROSCOPIC LIMIT, AND BEYOND.

Increased skill and ever-extending knowledge may enable the scientific worker not only to reach the utmost limit of inquiry in his time, but possibly to gratify that constant desire to see into the limitless region which lies beyond the bounds of actual investigation. This is the hope which encourages the thoughtful observer; for who would not consent to spend years in patient research, if by so doing he could succeed, as it were, in projecting his intellect, were it ever so short a distance, beyond the circumscribed region in which the senses can alone operate? Failures and disappointments may be endured if only the observer's mind be buoyed up by the hope that ere his nerve-tissues grow too old, and begin to fail, the longing of his intellect will probably be gratified. To many, indeed, who are unable or unwilling to look into the secrets of nature, such hopes and desires will seem unintelligible or incredible. They will be regarded as the idle fancies of an idle mind; and the ardent scientific inquirer will be pitied or condemned as a weak, foolish person who, like a child, is unable to repress his morbid curiosity to peer into the unseen, and his craving to know the unknowable;—as one deserving to be classed with simpletons and madmen, on the ground that it is absurd to suppose that a really sensible person would spend his life in hard work without remuneration, in preference to doing that which would enable him to gain wealth, and to live at ease, if not in luxury and enjoyment. And certainly it must be confessed that in few departments of research is there less prospect of gaining by success such rewards as are generally sought for, than in the one to which we are attached.

The microscopist, like the astronomer, is ever longing to get a little beyond the point at which he has already arrived. Each new fact gained by research seems but to indicate the existence of more and more important things beyond. Limit is reached and then surmounted, but soon a new limit seems to rise from the mists in the distance, towards which the worker is impelled by new hopes and desires. It is this never halting progress which distinguishes scientific from every other kind of inquiry, and particularly microscopical investigation, for it can never be completed. It deals with the illimitable. The boundaries of to-day are found to have vanished to-morrow, and the eyes and understanding begin to penetrate into regions which but a short time before had been considered far beyond the range of possible investigation.

He only who was quite ignorant of the many and great improvements constantly being made in our methods of research, and in the instruments required in investigation, would think of fixing any limit to the advance of microscopical inquiry. The records of the work of this Society contain many examples of progress towards and advance beyond barriers regarded not very long before, and by considerable authorities, as insurmountable. I well remember the time when, in many branches of inquiry, it might have been truly said that the optical instrument was in advance of the methods of examination; when our magnifying powers were higher than we could use without losing rather than gaining as regards the definition of delicate structure. As, however, time went on, this was changed. New and improved methods of examining tissues were discovered, and means adopted, by which excessively thin layers could be submitted to examination, and a power of five or six hundred diameters was no longer sufficient to enable the observer to see all that it was almost certain was to be seen. These remarks more particularly apply to a class of researches upon which I was engaged in 1856–60, concerning the structure and arrangement of the ultimate nerve-fibres in various tissues and organs. Indeed, I feel quite sure that at and before that time advance was actually retarded by the discouragement offered in some quarters, and the hypothetical objections raised to the use of very high powers, and more especially to the methods of preparation of the tissues that were necessary before they could with any advantage be submitted to examination.

Although at this time we can work easily with a twelfth and a twenty-fifth, the results of observation conducted with the aid of such powers are still regarded by some with doubt and incredulity; and if we draw attention to actual structure and arrangement discovered by the higher powers, which could not possibly be demonstrated with the aid of a more moderate lens, our statements may possibly be met with insinuations that what was advanced as the result of observation was, after all, discovered by the imagination only.

Our present limit of observation in investigations on the structure and action of the tissues of man and the higher animals, in my opinion, includes the use of magnifying powers of upwards of 2000 diameters. Objects considerably less than the hundred-thousandth of an inch in diameter can be studied with success, but how much less than these dimensions cannot, I think, be determined with accuracy at this time; for so much depends upon the character of the object, and a number of small points of detail as regards the mode of examination. All who are accustomed to work with high magnifying powers are well aware of the great advantages gained by some very slight change in the degree of illuminating power, the direction and concentration of the rays of light, and very slight and happy alterations in the focus, which may momentarily reveal to the mind new facts of the greatest importance after, perhaps, many hours of careful but almost profitless study.

But in other departments of microscopical research, our present means of investigation enable those familiar with the requisite methods of inquiry to demonstrate characteristics of structure far more intricate and minute than the remarks just made would lead you to infer. Various modifications in immersion lenses and in immersion media have greatly contributed to advance our knowledge of structure and action in the lower forms of life; and there is every reason to think that, as time goes on, methods of observation will be still improved and new methods discovered, and that in consequence conclusions already arrived at will have to be greatly modified or entirely changed. Not only so, but by the aid of photography things dimly seen by the eye may be very distinctly and correctly delineated, and with a perfection of accurate detail which a few years ago we should not have supposed to be possible. In all probability, the application of photography to investigations upon minute structural details will be carried far beyond anything yet reached, although it is really wonderful how much has been achieved up to this time.

As regards direct observation, with the aid of very high magnifying powers, upon animal tissues, a department of microscopical work which has engaged much of my attention during many years, I would remark that many observations have been made upon the structure and arrangement of the most delicate nerve-fibres less than the hundred-thousandth of an inch in diameter, and other tissue-elements of very small insects. With due care, facts are ascertained which could not have been demonstrated with the aid of object-glasses magnifying less than from 2500 to 3000 diameters. Not only is the demonstration of structure and arrangement satisfactory, but in many cases a conception of the action and working of the textures during life has been formed, which would not otherwise have been obtained. The exact relation of certain delicate nerve-fibres to the living matter of the nerve in special organs has been determined, and many elementary facts necessary for the determination of the changes constituting nerve action have been ascertained.

To my mind, however, the study, with the aid of high powers and various improved means of examination, of the phenomena which occur in living matter during life, transcends in importance at this time all other inquiries in which the Microscope takes a leading part. For these changes characterize every form of living matter at every period of its being, and in every condition of health and disease. In every form of living matter which exists or has ever existed the great mystery of life and death is enacted under our very eyes, but we have not yet been able to discover the exact nature of the change, though we can prove most conclusively that it is not merely mechanical or chemical, as some pertinaciously insist. No chemist or physicist has been able to explain the changes which do occur, or has succeeded in imitating them out of the living body. The most diverse structures and the most widely different chemical compounds are produced by changes occurring in particles of living matter which could not be distinguished from one another, and which are equally devoid of colour and structure. Many of the current theories on the nature of vital phenomena are not in advance of some that were propounded two thousand years ago; and yet men occupying high scientific positions are found to defend them, and to repeat again and again statements concerning the relation between the living and non-living, which are at variance, not only with facts familiar to every one, but are contradicted by the experience and knowledge every person possesses concerning certain vital phenomena of his own organism.

When a particle of living matter is increasing in size—is growing by taking lifeless matter into its substance, and, without itself losing anything, is communicating to certain of the elements of this non-living matter, or to combinations of these, the marvellous powers it possesses—movements take place, it may be in every part of the original mass. These movements are, however, always most observable, most active, and most extensive at some part of the circumference. Occurring now on one side, now on the opposite, it is very improbable that the movements in question are determined by any changes occurring in, or by force belonging to, any non-living matter in the vicinity of the living mass. These remarkable movements are universal in the world of life. They are more accelerated in some kinds of living matter than in others, but they are present in all, and in most are discernible at some time or other during the course of existence. Parts of the living matter continually tend to move away and separate from the rest, not in consequence of any attraction between these and surrounding matters outside, nor from any repelling influence exerted by parts of the mass itself upon other parts. There seems to be an active tendency on the part of different portions of a living mass to move away from the rest and so to detach themselves, and, having acquired vital power, to become independent, and to increase and then divide. This remarkable tendency on the part of every kind of living matter to divide and subdivide begins to operate as soon as the original mass has attained a certain size, and it seems to increase in intensity as the living matter approaches its proper dimensions. Invariably when a certain size has been reached, which, however, is different for different kinds of living matter, division occurs. The size is always, within certain very moderate limits, fixed and definite for the living matter of each particular species of living being. Among the lowest forms of existence, however, no definite limit of size has to be attained before division can occur. Particles smaller than the smallest particles that can be seen with the aid of the highest magnifying powers freely divide and subdivide, and there is reason to think that under certain conditions the division and infinite multiplication of the animate particles may continue for a considerable time, none of them attaining their fully developed form or dimensions. In higher forms of life, premature division of a living mass before it has grown for a proper time and reached a certain size, is very detrimental, and in many cases disastrous; for it is associated with degradation or even complete loss of formative, constructive, and developmental power. In some cases, by the rapid multiplication and division of the particles, the well-being of the whole organism is jeopardised, and death may be occasioned by the changes brought about by great increase and rapid growth and multiplication of certain particles of living matter belonging to the blood or to some of the tissues.

When a portion of a mass of living matter moves away from the rest, the moving portion invariably presents a convex surface, of which the portion in the exact centre is of course in advance of the rest and is the point towards which the movement of adjacent portions tends. It almost seems as if one minute portion had moved away from the rest and had dragged with it neighbouring portions, the power of the particles constituting which was not strong enough to act in opposition to it or to resist its influence. These seem to yield and follow the one or few particles in which the movement is strongest, and which seem to act the part of leader. It may be that certain particles here and there, having attained a larger size, or from being more active than the rest, move forward and determine the direction which is to be taken by those near. As far as can be seen, multitudes of living particles stream in one direction, the greater number being either carried along by the very few or irresistibly drawn onwards by them. The direction taken by flocks of birds and clouds of insects in still air or upon the surface of smooth ground, and shoals of fishes in water, is evidently determined and often very quickly changed in obedience to impulses affecting a very few of the great multitude of individuals of which the whole body is composed. These movements cannot, however, correctly be compared with those of a mass of living matter, inasmuch as there is no reason whatever for supposing that, in the latter, one particle has the power of choosing and determining, much less of conveying to its neighbours the results of its decision or choice and the request to follow.

It will, of course, be said by some that the remarkable phenomena we are considering are comparable with the movements occurring among iron filings under the influence of the magnet, or with the Brush discharge of electricity, the movements of the streams of highly attenuated moving matter in vacuum tubes, and other changes in place affecting particles of non-living matter. Surely it must be obvious to any one who thinks over the facts of the case that no true analogy has been shown to exist between the movements of living particles and those of any form of non-living matter. Nevertheless, the existence of such analogy is still maintained by a few, although the fallacy of the arguments upon which it is supposed to rest has been many times pointed out.

I dare say that for some time to come it will be most difficult to get a hearing for any views not in accord with the materialist tendencies of what is miscalled the *science* of our time. Thought is to be crushed, and any speculations are to be condemned which do not happen to favour the arbitrary dogmas of the purely physical school. But no doubt these attempts, like preceding ones of the same order made at different periods of history—although they may succeed for a time, and by them people may be driven away from the truth—will ere long be given up. They may be safely left to the gradual process of disintegration and ultimate dissipation by which these and such-like fancies of physical ingenuity will be disposed of.

As I have shown elsewhere, whenever tissue and other matters peculiar to living beings are to be formed, living matter undergoes change. In fact, the act of forming these things corresponds with the cessation of life in the particles.

Let us now consider the probable nature of the marvellous forces or powers which operate upon the material of the living matter, and determine the relations to one another of the elements or collections of elements of which it consists. By the relations established between the elements shortly before living matter dies, will depend the properties and composition of the resulting formed substances. The changes in each particular kind of living matter are somewhat different, but peculiar to and characteristic of that particular kind, and as regards it, constant and uniform. But no differences in the chemical composition or in any physical characters to be shown in different kinds of living matter, will in any way account for or explain the differences so remarkable in the formed material which is produced by or results from the death of the living matter. Nor do any properties of the particles yet discovered enable us to suggest a plausible physical hypothesis to account for the facts.

All those peculiarities in form, structure, and properties of tissue, which characterize the multitudinous forms of life around us, and which enable us to distinguish them from one another, are imposed upon the matter at the moment when it passes from the living to the formed state, or succeed as the result of a long series of changes then initiated. These peculiarities are not found in any ordinary matter, and can only be accounted for on the supposition that some force, property, or power exists which is peculiar and belongs to the matter only while its life lasts. This exerts but a temporary influence on the material particles, which are by it constrained to take up such prearranged positions with respect to one another as must necessarily result in the formation of definite compounds. To this prearranged disposition of the atoms of matter must every character of formed material and every distinctive property of tissue be traced back. This is, indeed, the cause of the varying form, structure, and property of every tissue and every living form in nature. The instant the influence of vital power in restraining the combination of atoms, ceases to be exerted, definite compounds are formed, but these are not living. The matter of which they consist has ceased to live. There are no phenomena occurring in non-living matter in any way comparable with these vital phenomena. Scientific opinion on these matters has lately been unduly influenced by a materialist party, which, like a political caucus, has assumed the right to direct thought and to promulgate the particular dogma which alone is to be accepted by the faithful.

If now I permit myself to pass beyond the point to which I have been led by actual observation,—if I try to advance beyond the present microscopic limit, travelling as it were upon the same lines as when observing within it, and try to realize the phenomena which occur during the early period of development of some comparatively simple vegetable tissue, a leaf for example,—I think the following description will not be far from the truth:—A mass of living matter, endowed with special powers working under certain definite conditions, takes up certain materials and increases in size thereby. Imparting to the new matter its powers, unweakened in force, as it grows, it soon divides into several portions, each of which in like manner grows and divides. The arrangement of the several masses, though fixed within certain limits, is determined not by any forces, powers, attractions, or repulsions acting upon all of them, but simply by the rate of growth of each, and division of the several masses under then existing external conditions; the dimensions each was to attain, as well as its properties, composition, colour, and the like being due to the life, force, or power each separate mass derived from the parental one which gave it origin, and from which it had been detached. But while the above phenomena are proceeding, changes are also occurring on the surface of each mass. The living matter in this situation, whether from the particles first formed, and being therefore the oldest, reaching the surface, and coming to the end of their living existence, or from some other cause I cannot say—passes out of the living state, and the component particles or certain of them combine, assume a certain form, and acquire physical properties they never possessed before. The formed material thus produced owes its colour, chemical composition, physical characters, internal structure, and the like, to the vital force or property in obedience to which the elements of the matter were made to occupy such positions and assume such relations with respect to one another just before death as must ensure the formation of the particular substances which result.

From the moment when the formation of the formed material occurred, the relative position of the several masses probably altered little. Growth may no doubt take place in certain directions by outgrowths, but one of the elementary parts with its surrounding formed non-living material cannot move from its place and get before or above any of its neighbours, as must at least be held to have been possible up to the time when its movements were restricted by the formed substances on its surface.

I would here remark generally, that if very little non-living matter is associated with the living matter, the latter may move in any direction with equal facility, and one part of a mass may place itself above or in advance of another portion just as easily as it could descend below it. But when a layer of formed material has been produced on the surface of the living matter, the entire elementary part becomes subject to gravitation in consequence of the quantity of non-living matter that is formed.

There is not, I think, any good reason for accepting the conclusion that one of a collection of elementary parts, at any period of development, can sympathize or otherwise influence the actions of others, as Virchow seems to think. The suggestion that any force or power acting, as it were, from a centre, governs, regulates, and determines the changes taking place in surrounding and more or less distant particles, is, in my opinion, inadmissible. We might, with as much show of reason, refer the harmonious action of the several parts of the adult organism to some controlling or governing power situated we know not where, influencing, we know not how, actions of many different kinds occurring at considerable distances from the seat of its existence. Although very high authorities have given their sanction to views of the kind, and have advocated the existence in connection with each individual organism of some power or force capable of operating through material of even considerable thickness and of controlling matter at a distance, I venture to assert that the conclusions are not supported by the results of observation and experiment. The idea of one particle of living matter influencing other particles at a distance from it, much less sympathizing with or being affected by vital changes occurring in them, cannot, I think, be entertained by any one who has studied the phenomena as they occur in living beings.

One can indeed conceive tissues of the most elaborate character, and new matter of the most wonderful properties and most complex composition, being developed in the most regular and orderly manner without supposing that any governing or controlling power acts upon them all, as it were, from a centre. That the most wonderful order is manifest in the arrangement of the component elementary parts, say, of a growing leaf, must be obvious to every one who has examined it; but I feel confident that as soon as each living particle has been detached from the mass which preceded, it is no longer influenced by the latter, and does not influence neighbouring masses. Each may be pressed upon by its neighbours, and press upon them in turn during growth, but there is no reason to suppose that any one determines the composition, governs the motion, or regulates the action of others. The nutrient matter is distributed to all by vessels or channels running amongst the several collections. Those elementary parts farthest from the nutrient supply will grow more slowly than those nearest to it, but no formative or constructive or synthetic or analytic influence is exerted by the nutrient fluid upon the living matter, nor by the several elementary parts upon one another. Each is under the influence of the vital power associated with the matter of which it in part consists; and whether each can exist independently if separated from its neighbours, or dies soon after it is detached, depends not upon any influence exerted upon it by these neighbours, but simply upon the inherent capabilities of its own vital power, transmitted to it from the living matter which existed before it, and of which it once formed a part.

Nevertheless, each individual elementary part, say, of a leaf, or other organ or tissue, must not in any case be regarded as an individual, independent, or self-dependent organism, for it constitutes but a part of a highly complex whole which has been gradually formed in accordance with a definite structural plan and arrangement, foreseen and prepared for as it were from the very first.

It is only by attributing the observed phenomena to the operation of a special force or power, having no analogy whatever with any known inorganic forces or powers, that a reasonable explanation of the facts can be framed. The phenomena which have been referred to cannot correctly be compared to any processes or actions which occur independently of life, neither can any true analogy be pointed out between these and any physical or chemical changes or actions of which we have at this time any knowledge or experience. That the formation of all tissues and organs is governed by "law" is no doubt true, but the "law" is unknown, and whatever may be its terms, the mode of its operation upon matter is as different from that of any laws that are known to operate in the non-living, as are the known and observed facts of life from those of the inorganic matter of the world.

Now as regards the nature of the actual phenomena of living matter which are at present beyond the range of observation, at least two diametrically opposite ideas are entertained.

1. There is the commonplace notion that structure exists which will account for the actions which take place, but that the details of this supposed structure are too minute or too delicate to be demonstrated by any magnifying powers which have yet been constructed. For this idea there is no sufficient justification. It is one of those assumptions in elaborating which the modern materialist is so ingenious. In this way he struggles, and with some success, to postpone for a time the inevitable fall of the system he has endeavoured to make popular in spite of the overwhelming evidence of facts against it. Here I must remark that the word "structure" as employed by physicists is used in a sense

utterly distinct from that in which we use the word. This is evident enough if we consider what is understood by the "structure" of a crystal and the "structure" of an organ or tissue. The first "structure" at once disappears when the crystal is dissolved and reappears whenever it is formed. The other structure results, or, as some say, is evolved, only after many series of changes of a very complex character have been completed. Once destroyed, the structure of an organism can only be restored by a long course of similar developmental processes. In fact, there is not the faintest analogy between the structure of an organism and the structure of a stone—the structure due to the operation of living forces and the structure which is inherent with other properties in non-living matter.

2. There is the view supported by myself, and in favour of which I have adduced evidence which I believe to be perfectly convincing, that living matter has no definite structure whatever—that, in fact, its particles, and very probably their constituent atoms, are in a state of very active movement, which renders structure and fixity of arrangement impossible—this active movement being an essential condition of the living state, which latter ceases when the movement comes to a standstill. According to this view the idea of structure as belonging to living matter is inconceivable.

Now we know of no state in which non-living matter exhibits any analogy with matter in the living state, so that the cause of the state under consideration must have reference to the living state, and to that only; and to reassert, as many continue to do, that the phenomena manifested by living matter are to be accounted for by the properties of the material particles, is silly and perverse; and though the view of the peculiar nature of the vital power here put forward and based upon a consideration of the phenomena of living matter, may be ridiculed by materialists, every one who thinks over the matter will see at once why this course is taken by them.

Professor Huxley, in his article "Biology," in the 'Encyclopædia Britannica'—without defining what he means by the words "molecular" and "machine"—assures his readers that "a mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend, on the one hand, upon its construction, and, on the other, upon the energy supplied to it; and to speak of vitality as anything but the name of a series of operations, is as if one should talk of the 'horologity' of a clock."* This is the sort of teaching that has long retarded the progress of thought, and affords an example of the puerile objections palmed off on the public as scientific criticism, and supposed to be sufficient

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* Huxley, Article "Biology," Encyc. Brit.

to controvert evidence founded upon observation, and arguments based on facts which any one may demonstrate. Is it not most wonderful that Professor Huxley can persuade himself that a single reader of intelligence will fail to see the absurdity of the comparison he institutes between the invisible, undemonstrable, undiscovered "machinery" of his supposititious "molecular machine" and the actual visible works of the actual clock, which any one can see and handle, and stop and cause to go on again?

Magnify living matter as we may, nothing can be demonstrated but an extremely delicate, transparent, apparently semi-fluid substance. But observations on some specimens under certain advantages of illumination, and with the aid of the very highest magnifying power that can be brought to bear, favour the conclusion that living matter should be regarded as consisting of infinite numbers of infinitely minute particles, varying much in size, and possibly capable of coalescing, free to move amongst one another, as they exist surrounded by a fluid medium which contains the materials in solution for their nutrition, and other substances.

One may transport oneself in imagination into infinite space, amid the never-ceasing vibrations visible and invisible—"The lucid interspace of world and world, where never creeps a cloud, or moves a wind," and may perhaps all but see combined in one mental image, as they ever course through space, suns and worlds and systems. And although at first the mind is almost lost in the contemplation of the infinite physical vastness presented it, it is nevertheless able to seize in some degree a more than shadowy conception of the exactness and regularity of the eternal movements, and to recognize the never-ceasing operation in the material universe of inflexible, unchanging law.

But he who in imagination can succeed in mentally placing himself amid the atoms in the interatomic spaces of a living particle, will be in the very heart as it were of an infinity of a very different order—infinite movement and change affecting infinitely minute particles, so very near to one another that the matter of one may as it were run into that of the other, and the masses divide and subdivide again. Of all this movement and change of particles how very little of what occurs in a portion of matter not more than the one hundred-thousandth of an inch in diameter can be comprised in one mental image? But beyond all this there is the power of prospective change, acting through years it may be, which is somehow associated with the minute particles of living matter, as well as many complex phenomena of which the mind cannot take cognizance as a whole, but must consider, as it were, one by one in several successive pictures.

Could we peer into the very substance of the living particle itself as it was increasing in size and communicating to non-living matter its wonderful properties, what should we see? What is it that happens at the moment when a little complex organic matter dissolved in water passes from the non-living to the living state? Should we see atoms being arranged and entering into new combinations according to some physical properties inherent in the very matter—atoms combining according to their chemical affinities; or should we see the complex chemical compounds of the pabulum being changed, their elements being somehow torn asunder from their combinations, or rather quietly separating from one another in obedience to some force or power of which we cannot form any accurate conception? The most extraordinary active atomic movements must be taking place, and in the quietest possible manner. Certainly the phenomena which accompany ordinary chemical decompositions in non-living matter do not occur. No two things in this world can be more dissimilar than man's chemical laboratory and nature's laboratory in this living matter. That the formation of the germ is to be accounted for by the operation of the ordinary forces of matter is one of the most absurd of absurd propositions; but that the idea of such an origin should still be entertained and taught by a physicist or chemist is unaccountable.

There are no actions in non-living matter with which the actions of living matter can with any degree of fairness or accuracy be compared. No argument in essential particulars can be pointed out which would justify the use of the word "analogy" without doing violence to truth and cheating the reason. To maintain the identity of the vital and inorganic forces on the ground of some fancied analogy between vital action and crystallization is most wrong and wilfully misleading, for the fallacy has been many times exposed and exploded. Between a crystal and living matter there is not the slightest analogy, for the one can be destroyed and caused to re-form as many times as we like, while the living matter cannot be even dissolved. In the attempt to dissolve it, it dies, and cannot be reproduced.

It is obvious that before particles of living matter pass from the living into the formed state their component atoms, or groups of them, must somehow be made to take up a definite position with respect to one another. Such changes of place as must occur can only be brought about by some peculiar force, property, or power, the action of which is temporary. Seeing that the changes in question can take place only while matter is in the temporary living state—this matter having been detached from matter in the same living condition—the force or power in question must be of an exceptional nature, and of an order different from that to which the ordinary forces or powers of non-living matter belong. This wonderful living power which is postulated causes the atoms or the particles of the matter to take up certain positions, favourable to their combination in a certain definite manner. Thus certain substances are formed which have a peculiar chemical composition, and in certain cases special properties and endowments not possessed by substances that can be formed in any other way. It seems to me it would be as unreasonable to maintain that the bricks, or rather the clay of which they are made, or the silica and alumina of the clay, or the properties of the elements entering into the composition of these substances, design, fashion, and build the house, as to assert that the formation of living things is due to the physical properties of the materials of which their bodies are composed. Vital power impresses as it were its seal upon the matter—upon the structures of the living organism—and ought surely therefore to be considered as above and superior to the mere stuff that it moulds. Vitality, or vital power, forces, bends, arranges, and fashions just as man himself moulds and fashions the clay he works with, only silently, invisibly, more perfectly, and in a definite and prearranged manner, and without mind or will or ingenuity or instruments or organs.

Judging from the facts, is it not indeed more probable that the ordinary properties, the attractions, the affinities, of mere matter are in suspension rather than in action while the matter continues to be in the living state? When these properties and affinities come into play, do we not get from the matter that was alive albuminous matters, fat, and other things, of known properties and definite composition? But neither these nor any definite compounds existed when the matter was living. They came into being at the moment of its death. The idea of these substances existing in the living matter is inadmissible, for if they were there, some of them could be demonstrated. Such a substance as fatty matter cannot, of course, exist in the living state; fat cannot grow and form fat out of materials which contain the elements of the substance in different states of combination, any more than granite can. If it be conceded that during the living state the ordinary properties and affinities of the matter are suspended, it will be admitted that none of the ordinary properties of material particles can be reasonably credited with the ability to interfere with the exercise of affinities; and therefore it seems reasonable to conclude that some totally different power, *vitality* or *vital power* (which same, unlike the ordinary properties of the matter, is lost or ceases to act when living matter dies), is the true cause of the exceptional state in which the material particles are held while the matter remains living.

But thought may take us yet further. Gradually passing inwards towards the centre, through vast concentric layers of particles, we arrive at last in imagination near the centre of a particle far too minute to be visible, where the atoms of lifeless matter first live. As to the actual nature of this wonderful change which occurs, we are, and from a purely physical point of view must remain, in darkness. For it is certain that the new temporary living state is absolutely distinct from the non-living state in which the matter existed but an instant before. Before long this will, I doubt not, be generally admitted by those acquainted with the facts, and not biassed by previous confessions or beliefs.

It is invariably in living matter devoid of structure and form, that all those wonderful actions of surpassing interest which result in the development of form the most striking and structure the most elaborate, are carried on. Forces or powers, but of a non-material order, transmitted through succeeding particles of the same kind, and continuously operating, it may be upon vast quantities of matter, through centuries or centuries of centuries ("millions on millions of years"), are the activities by which the rearrangement of the elements under certain fixed conditions which eventuate in definite and predetermined form, structure, and composition, is brought about. The changes, conversions, formations in question, at present invisible and undemonstrable, require considerable time for their completion. Compared with the visible phenomena which succeed them, and which may be watched, described, and delineated by us, they are slow indeed. During days, weeks, and months, in darkness and in silence, arrangements and rearrangements of the most complex character incessantly and quietly proceed, as we say, in obedience to *laws* (though we do not *know*), ere the first visible traces of the new being can be discerned by the most careful investigation.

Remember that the changes in question affect a mere modicum of matter. A grain, nay, the hundredth, the thousandth part of a grain, and far less than this may at one time constitute the material substance from which springs a tree that in its maturity will comprise tons of matter, every grain of which will be stamped with individuality. Is it not, then, most strange that in these days which surpass all previous time in the passion exhibited by men to see into the nature of things, that attention should be so much absorbed in considerations relating to the mere matter of which a living thing is made, while the study of the forces and powers which have effected the forming and shaping of the material substance is not only almost wholly neglected, but positively discouraged? And yet these forces or powers fashion the germ and cause it to be like its predecessors, or modify its character and cause it to give rise to forms perhaps not before attained. With what shall these forces of the living world, operating so marvellously upon infinitesimal particles of matter, be compared? The changes have been likened to those which take place in the formation of crystals, which can be dissolved and caused to re-form as often as we choose; to the aggregation of particles of lifeless matter which can be made to separate or aggregate as we will; to machines which are made by us in separate pieces and afterwards put together; and to many other things between which and living particles there is not the faintest resemblance or the slightest analogy. Uninquiring, unthinking persons have been, and are at this time, misled by crude and false comparisons, and deceived by forced and fancied analogies. The coarse materialism of our day ought long ago to have been dismissed with scorn as unworthy of the age in which we live, and of the acceptance of any one who would not disgrace himself by helping to force thought back again to the point it had reached more than two thousand years ago.

No one acquainted with the facts of vital change can doubt that phenomena of the same order as those in operation to-day attended the development of primeval forms of life. For not only do we meet with living matter producing the same structures as existed during early periods, but it is probable that some of the living things now growing and multiplying are identical with some that existed in the very dawn of life-history. Unbroken *continuity, descent, derivation,* in operation through the ages without change in power or property, or alteration in form or composition; *repetition* without gain or exaltation; *continuous descent* without degradation or improvement; monotonous succession without progression or advancing evolution. Nevertheless, we are expected to accept the dictum that amid these myriads of myriads of similar organisms, here and there one more fortunate or more gifted than the rest—we are not told why, when, or how—became endowed with the marvellous power of endless modification. We are asked to believe that rigid laws uniformly operating with the same consequences, for ages, suddenly changed, and that long-imposed uniformity gave place to capability of differentiation. But if we try to realize what, according to the terms of the hypothesis must have happened in the living matter, into what a sea of fantastic conjecture do we plunge! The new or modified powers must have originated in or emanated from particles in the very centre of minute living spherules. When we consider the minuteness and insignificance as far as the mere matter is concerned, of the living particles we are referring to, many will, I think, be inclined to admit that it is at least as probable that new forms of living matter of this infinitesimal minuteness originated anew, as that forces which had been in operation for ages, under inexorable unchanging laws, were entirely and suddenly changed or removed, and replaced or supplemented by additional and very different forces obeying very different laws.

Moreover, as no direct or positive evidence of a reliable character has yet been obtained in favour of the direct conversion of non-living matter of any kind into a living form, while there is nothing to indicate that the passage from the non-living to the living was effected by gradual change, as has been suggested by some, it is as reasonable to assume that several infinitesimal life-forms with very different powers of development sprang at once into life, though the ultimate form to be assumed was postponed for ages, as that one single living form only was so formed with the power both of endless monotonous repetition, as well as of infinite and never-ceasing capacity of variation and change, one or other of these opposite attributes being accidentally exercised or capriciously taken advantage of by such of the descendants as were assured that they were, above all the rest, most fitted to survive.

Doctrines of evolution are, no doubt, an advance upon the direct mechanical formation of fully formed organisms hypothesis; but although some evolutionists have so expressed themselves as to lead us to infer that an idea so absurd as the above had been entertained, it need scarcely be said the inference is their own and totally unfounded, suggested by themselves for the satisfaction of ridiculing it and exposing its inferiority to their own hypothesis. No doctrine of evolution yet put forward seems to afford any help to those who are familiar with the characters of the living matter of different organisms, as far as these can be elucidated by any means at present known. Evolutionists generally do not take cognizance of the difficulties which are so patent to microscopical observers. Some of them have hardly condescended to notice the living matter, out of which and by which all the forms of life they profess to account for are developed. It is true that it has been suggested that there are structural differences in the apparently similar matter, which structural differences result in the production of such dissimilar beings; but speculations concerning hypothetical structure are as futile as those which deal with the hypothetical form and properties of the hypothetical inhabitants of Jupiter.

All living matter is, I repeat, structureless, and it is to the power rather than to the mere matter we must look for the explanation of the marvellous differences in the beings evolved by different kinds. The similarity of various embryos of different animals has often been alluded to, and it has been said, for example, that at a certain period of development the embryo of man could not be distinguished from that of the dog. That there is a general rough resemblance is perfectly true, but, on the other hand, any one who examined the minute structure of corresponding tissues and organs, would not find the likeness so great as is supposed, while he would be struck with the great number of points of difference. Not one structure could be found in any part of one embryo which did not exhibit peculiarities by which it could be distinguished. It would, therefore, scientifically be more correct to say that the embryos were *not like one another*, than that *they were like*. But any argument based upon the likeness, if it existed, would not help the evolutionist, inasmuch as the "likeness" is far greater at an earlier stage of existence, before any form or structure whatever has appeared. Every living form comes from an equally structureless material, and the forms near one another in the scale are not more like one another than they are like forms far above or far below them. If, for example, the evolutionist would examine embryonic living matter at a very early period of development, he would discover not only that man and dog were not to be distinguished, but that not one form of living matter could be distinguished from any other form in nature; nay, the living matter which might become dog or man could not be identified by any means at our disposal, or distinguished from that which belonged to amœba or plant, and yet it is put forward as a discovery of recent date that certain properties manifested by the tissues of animals also characterize some of those of plants.

But after all, the assumed likeness is but a likeness in certain general points, and those who wish us to draw certain conclusions from their statements, ought to be asked to point out how it is that every cell, every tissue of the embryos they regard as being alike or identical, exhibits peculiarities and individual characteristics of its own as regards elementary arrangement, rapidity of formation, rate of growth, duration of existence, and a number of other points. Again, the statements about the changes occurring during development in the lower animals being represented by identical changes occurring during the earlier periods of development in the higher, are correct only when taken in a very rough and general way. Such phenomena, it is said, show unity of plan, and favour the hypothesis of the descent of jelly-fishes from sponges, and of man from apes. No doubt they do if the mind is already prepared to receive such ideas. Those, however, who really study the operations of nature in her inner recesses where and while she is at work, will certainly often find that where identity is affirmed, diversity really exists. Rough general resemblances can no doubt be pointed out, and be made much of, by those who do not look too closely or intently; but those who examine minutely and patiently will find that in very many cases the general resemblances will be outnumbered and outweighed by specific irreconcilable differences and individual peculiarities.

If then we examine living matter in that early period of development ere any structural peculiarities whatever have been manifested, we shall be face to face with the problem of life. For it is at this time, when the matter is without form, that the dispositions of the material particles, which at length result in the development of form, are made. Preparation is made for the division of the mass of living matter into several portions, and for the orderly disposition of these in respect of one another, as well as in respect of the new masses which at some future time are to be detached from them. Throughout the whole period of the life of many organisms, similar wonderful changes are continually taking place, at least as respects the living matter of certain parts and organs; but we have no means of distinguishing the living matter which continues monotonously repeating similar changes, from living matter which divides and subdivides into masses, which in turn give rise to successive generations of living particles, which may differ from one another and from all that have gone before, in *power.*

As far as I am aware, no form of the doctrine of evolution yet enunciated takes into account the phenomena of the living matter in which and by which all the changes recognized and professed to be explained are carried on. And yet it is only by these actions in living matter that evolution can be made to appear a plausible hypothesis. Only by carrying out very careful investigations on this formless, structureless living matter can we reasonably hope to obtain anything approaching an accurate conception of the wonderful working of real living nature. It seems to me that the "nature" of the evolutionist is but a fanciful and highly coloured picture in which ideas suggested by investigations in stockyards and shambles are depicted, with the addition of the horrible scenes assumed by a vivid imagination to be enacted in the supposed everlasting fight for existence and scramble for mastery, in which conquerors are always being conquered by creatures just a shade more fitted to survive than themselves. Here is creation by destruction in a never-ceasing scramble going on for millions on millions of years, in which the only thing certain seems to be that the greatest misery is assured to the greatest number; life succeeding life, without good or reason or joy or hope; peaceful nature a continual massacre of experimental forms of life to be soon succeeded and superseded by other experimental forms to be massacred in their turn, and these by more; a constant struggle to survive, in which success is rewarded by extermination. The "nature" of evolutionists is a very strange nature indeed, in which oppression, destruction, and tyranny seem to be the chief agents in creation and formation, development and advancement.

But besides the evolution of living forms and of the different organs, we are to believe in an evolution of matter, an evolution of worlds, of suns, of systems. Religion, law, and justice, art, science, and even thought are all products of this universal, never-ending evolution. But what is evolution, and who has given to the term an accurate definition? We shall be told there is evolution and evolution. One man's evolution goes too far, another's not far enough, and there is no general agreement as to what is meant by evolution, and whether the use of the term should be restricted to the living world or extended to the universe—though it must be obvious to any one who considers the question that the evolution of a living form and the evolution of the matter of a stone are as far removed from one another as are the question of the nature and scope of Infinite Power and the nature and properties of a gas or a metal.

Herbert Spencer has defined his "evolution" to be a change from an indefinite incoherent homogeneity to a definite coherent heterogeneity, through continuous differentiations and integrations. But is not every one of these polysyllabic words as elastic as the word the meaning of which they are to explain? Every assertion made is wanting in proof, and most of the words may be used in totally different and even in opposite senses.

Any one who ventures to express a doubt concerning the absolute correctness of the assemblage of vague and even contradictory conjectures comprised in any hypothesis of evolution, is in danger of being abused and called names. He may be denounced to the world as a contemptible person who has made a vile and abusive attack upon some infallible authority who affirms himself to be the real discoverer of all the secrets of all the molecular machinery of creation. We now live under the most ridiculous of all forms of despotism. It has been said that we must accept such and such views or be debarred from accepting anything! But is it possible for any unbiassed person to accept implicitly doubts, vague suggestions of what may be, or can be, or might be,—speculations, hypotheses, conjectures concerning things that lived under conditions which are in great part only conjectural? Probably no living person accepts as it stands 'The Origin of Species,' and it is doubtful whether the first chapter, or even the first sentence of the first chapter, would hold its ground without considerable alteration and qualification if subjected to searching critical examination.

The facts known to microscopical observers in connection with the act of living of the smallest particle of the simplest forms of living matter are no more to be accounted for by any of the extravagant crotchets lately advanced as explanations of the facts, than are the general broad phenomena of nature which are under the observation of all. Evolution is a wholly satisfactory explanation only to those whose minds have been trained to submission to evolutional authority, and who have brought themselves to regard things as they have been told they ought to regard them, instead of venturing to use their senses, and reasoning on the facts presented to their observation—and indeed see for themselves with their own eyes, instead of accepting, without ever seeing, what they are told has been seen by eyes which are supposed to be specially privileged to see.

As evidence of the nonsense often advanced in favour of some form of evolution, let me quote a few sentences from an article on "Butterfly Psychology," published in the 'St. James's Gazette.' Like most advocates of evolution, the writer has the knack of telling his story in such a pleasant way as to make people imagine that he is explaining the nature and causes of things he describes, while in truth he is doing nothing of the kind. He explains nothing at all, but merely announces astounding assumptions based upon conjectures of his own, or of others.

"In early life the future butterfly emerges from the egg as a caterpillar. At once his many legs begin to move, and the caterpillar moves forward by their motion. But the mechanism which set them moving was the nervous system, with its ganglia working the separate legs of each segment. This movement is probably quite as automatic as the act of sucking in the new-born infant. The caterpillar walks, it knows not why, but simply because it has to walk. When it reaches a fit place for feeding, which differs according to the nature of the particular larva, it feeds automatically. Certain special external stimulants of sight, smell, or touch set up the appropriate actions in the mandibles, just as contact of the lips with an external body sets up sucking in the infant. All these movements depend upon what we call instinct—that is to say, organic habits registered in the nervous system of the race. They have arisen by natural selection alone, because those insects which duly performed them survived, and those which did not duly perform them died out. After a considerable span of life spent in feeding and walking about in search of more food, the caterpillar one day found itself compelled by an inner monitor to alter its habits. Why, it knew not; but, just as a tired child sinks to sleep, the gorged and full-fed caterpillar sank peacefully into a dormant state."

Of course all this may have been written in joke. The writer may possibly be laughing at evolutionists. The "inward monitor" of the "gorged and full-fed caterpillar" undoubtedly looks rather suspicious, but one hardly likes to hint at anything so serious. Evolutionists will, I dare say, repudiate such "evolution" as a mere travesty, but it is quite time that half-a-dozen evolutionists who agree on main points should clearly state their belief.

In conclusion, let me ask you as students of nature's processes, whether you have not seen enough to convince you that the revival of the assumption which has been abandoned and reintroduced many times during the last few centuries, that the lifeless is the sole origin of the living—that in fact the non-living and the living are one—is now unjustifiable, and cannot be reasonably entertained. This monstrous fallacy, though taught with the greatest confidence, is based on assumptions, and is supported by arbitrarily selected facts, and by not a few misrepresentations and dogmatic assertions. Whenever any form of this false doctrine has been successfully forced into popularity, it has led to the adoption and propagation of the most grievous errors and grotesque conceits.

IV.—*On the Conditions of Orthoscopic and Pseudoscopic Effects in the Binocular Microscope.*

By Professor E. Abbe, Hon. F.R.M.S.†

(*Read 12th January,* 1881.)

In a paper which appeared in the September issue of the 'Zeitschrift für Mikroskopie,' ‡ the author briefly pointed out a principle by which the well-known diversity of stereoscopic effects in the binocular Microscope — orthoscopic or pseudoscopic vision — is brought to a general and very simple expression, defining the character of stereoscopic action in binocular arrangements of any kind, *independently* of the composition of the optical apparatus.

The principle in question is based on the consideration of the so-called "Ramsden circle" at the eye-point of the ocular, which is a reduced image of the objective's clear aperture, and represents the *common* cross-section of all delineating pencils at their emergence from the ocular. As in the monocular Microscope all rays gathered by the circular aperture of the objective are transmitted through the system, the Ramsden circle is a true circular figure which is conjugate, point for point, to the clear aperture. Stereoscopic vision, however, requires that the delineating pencils shall be so divided that one portion of the admitted cone of light is conducted to one eye and another portion to the other eye. Hence the Ramsden circles above the eye-pieces of a *stereoscopic* Microscope must always be reduced to two dissimilar figures, representing dissimilar parts of the full circle of a monocular Microscope; for different (e. g. opposite) portions of the incident cone obviously correspond to different (opposite) portions of the emerging pencil. If now the division of the pencils, by whatever optical means it may be effected, is effected in a symmetrical way (which is usually the case in binocular arrangements), their cross-sections above the oculars must be reduced to semicircles, representing one of these two arrangements O or P :—

Fig. 36.

This being premised, my proposition is :—

The only condition necessary for *orthoscopic* effect in any

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† The original paper is written by Prof. Abbe in English.—Ed.

‡ "Beschreibung eines neuen stereoskopischen Oculars, nebst allgemeinen Bemerkungen über die Bedingungen mikro-stereoskopischer Beobachtung," Zeitschr. f. Mikr., ii. (1880) p. 207. See also *infra*, "Microscopy."

binocular system is that the semicircles in question should be depicted according to the diagram O, and for *pseudoscopic* effect, according to P; *all other circumstances, except this one, being immaterial.*

An equivalent expression of the same rule (implying, however, the tacit assumption that the observer's eyes are kept concentrically to the axis of the oculars) would be: Orthoscopic vision is always obtained, when the right half of the right pupil and the left half of the left pupil only are employed—pseudoscopic vision in the opposite case; and whenever that condition is fulfilled, the same kinds of visual impression will always result. It is quite indifferent, whether the effect is obtained with crossing or non-crossing rays, whether the image be erect, or inverted, or semi-inverted, and whatever elements (lenses, prisms, mirrors, &c.) may be components of the optical arrangement.

This proposition—which is an outcome of a purely theoretical research into the circumstances of *solid* vision in the Microscope—may be verified by various experiments. The author has applied it, in the "stereoscopic ocular" described in the paper quoted above, for obtaining at pleasure *true* orthoscopic or pseudoscopic vision with a binocular arrangement which in itself is non-stereoscopic.

It has, however, been objected to this method in most decided terms,† that orthoscopic vision is not obtained in binoculars with non-erecting eye-pieces, unless the axes of the two halves of the admitted cone cross each other; and this view has been assumed to be a sufficient basis for deciding *à priori*, without any experimental trial, that the pretension of stereoscopic action of such an arrangement as the author has described must arise from confounding imagination effects with true stereoscopic impressions. It will therefore be useful to give the demonstration in detail of the principle pointed out above, which I did not think necessary in the original paper.

My consideration is based on a few suppositions, which are generally adopted. These are: ‡—

> Stereoscopic effect (both in ordinary and in microscopic vision) depends on difference of perspective in the two eyes of the observer, i. e. on different parallactic displacement of consecutive layers of an object in their projections to the two eyes.
>
> True stereoscopic (orthoscopic) effect is *always* obtained when the *right* eye sees the *nearer* planes of the object

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† This Journal, iii. (1880) p. 1088.

‡ As to these premises, I refer the reader to Dr. Carpenter, 'The Microscope,' 5th ed. § 28 *et seq.*

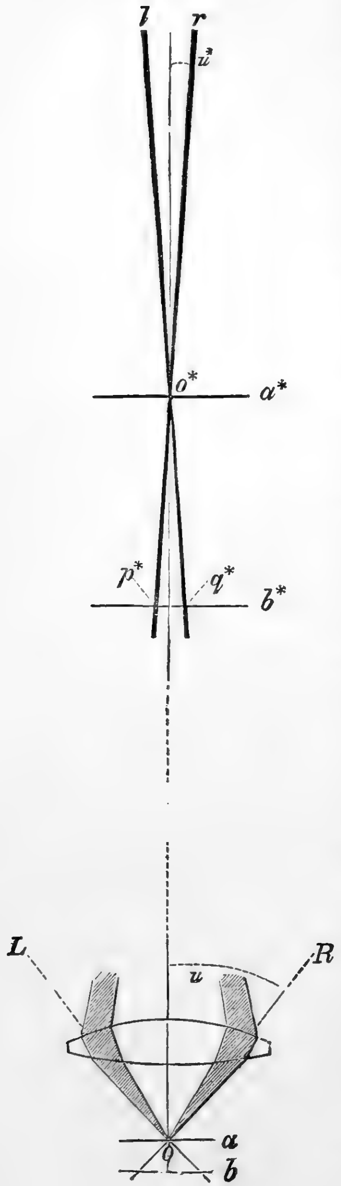
> displaced to the *left* hand (and the more distant planes to the right hand) in opposition to the projection of the same object for the left eye; pseudoscopic vision results from projections of an inverse character.
>
> Stereoscopic effect in the binocular Microscope arises from an opposite perspective character of *images* which are projected by incident pencils of different inclination at the preparation—i. e. which are delineated by different parts of the objective's clear aperture.

These premises being conceded, the strict and direct way for discussing the phenomenon of stereoscopic vision in the Microscope must necessarily start from a consideration of the *three-dimensional image* which is projected to the observer's eye by the total Microscope. For in microscopic vision we do not see the object itself, as in direct vision with the naked eye; we see the virtual image only, which is finally delineated by the ocular, and is a *solid* image with a certain amount of depth when the object is a solid object. This solid image—and not the microscopical object—is placed in the binocular Microscope under circumstances similar to those of common objects in ordinary binocular vision. Therefore the perspective projections of this image ought to be compared to the projections of solid objects in ordinary vision, in respect to which the criteria of orthoscopic and pseudoscopic vision have been defined.

With this in view, let a, b, in Fig. 37, represent two different planes of a solid object, to which a Microscope has been focussed, and R, L two incident rays, or pencils, departing from the point o with opposite obliquity and transmitted through opposite portions of the objective's clear aperture. Neglecting all intermediate elements of the optical system, and considering only the final virtual image of the object which is delineated by the total Microscope within the range of distinct vision, let a^* and b^* indicate those plane images which are conjugate to the planes a and b of the object, and r, l the final emergent pencils (crossing at the point o^* conjugate to o) which result from the incident pencils R, L, and are admitted to the pupil of an observer's eye at E.

The directions r, l now indicate the difference of perspective which produces the effect of solidity in the image. Whenever this image is depicted by *one* of the incident pencils only, the other being shut off from the pupil, the consecutive layers a^*, b^* (and all intermediate ones) are viewed either along the direction r, or along the direction l. Point o^* of the plane a^* is now seen projected either to point p^* or to point q^* of the plane b^*, and opposite parallactic displacement of consecutive planes is thus introduced into these *partial* images.

Fig. 37.



The divergence of the delineating pencils at an optical image is always reduced, in comparison to the divergence of the incident rays at the object, in proportion to the linear amplification of that image. Although, therefore, the angle between the lines of perspective (*r*, *l*) in the case of microscopic vision is very small only, there is no other element which can account for a different perspective of the images obtained through opposite portions of the aperture.†

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† It may, at first sight, appear surprising, that the very slight angle of perspective, which is allowed for the microscopic image, should be competent to exhibit an appreciable difference of projection. But it must be noted that the *solid* image depicted by an optical system is by no means similar to the solid object. The amplification of the depth varies always with the square of the lateral amplification; therefore an *extra* amplification of the depth is obtained, which increases exactly in the same degree as the divergence of the delineating pencils *de*creases. Owing to this general feature of optical action, the small divergence of the emergent rays, *r*, *l* must produce, in the projection of the *distorted* image, parallactic displacements of the same amount as would result from the original divergence of the incident rays R, L, in an image of uniform amplification.

Let δ and δ^* denote the axial distances of consecutive planes in the object and image ($\delta = a \ldots b$, $\delta^* = a^* \ldots b^*$ in Fig. 37), n and n^* the refractive indices of the media at object and image, N and M the linear amplification of the two images at a^* and b^*, we have quite in general and in perfect strictness, for every kind of optical system, and every position of object and image,

$$\frac{\delta^*}{\delta} = \frac{n^*}{n} \cdot \mathrm{N\,M};$$

and this gives

$$\frac{\delta^*}{\delta} = \frac{n^*}{n} \cdot \mathrm{N}^2$$

A glance at the diagram will at once show that a parallactic displacement of the *upper* plane of the image to the *left* hand must occur when this image is seen by means of the pencil r, which is inclined to the right hand, and *vice versâ*. The pencil r represents the right portion, and l the left portion of the total cone of emergent rays, which would be transmitted to the eye, if the full aperture of the objective were active. Considering now the criterion of orthoscopic vision with the naked eye, which has been indicated above, the conclusion must be: right-eye perspective of the solid *image* is always obtained from the right-hand portion of the emergent pencils, left-eye perspective from the left-hand portion; *and it is quite immaterial, as regards this result, which portion of the emergent rays is admitted by the right or the left part of the objective.*

Hitherto the perspective character of projections by pencils of opposite inclination has been defined in respect to the three-dimensional *image* which is seen like a real object with the naked eye. For defining now the character of the same projections in respect to the *object*, it is sufficient to take into account a general proposition of geometrical optics, which shows:—The axial sequence of the layers in an image is always *conformable* (and never the opposite) to the sequence of the conjugate layers in the object, whatever may be the composition of the optical system, provided the layers in question be delineated in a continuous manner (or what is an equivalent expression—at one and the same side of the principal focus of the system). As this condition is always fulfilled under the circumstances of microscopic vision, the final image of the Microscope is always *erect* in respect to depth, whether it be erect or inverted or semi-inverted in respect to the lateral dimensions. Now the character of solid vision (orthoscopic or pseudoscopic)

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if the consecutive planes are very close together (and M = N). Denoting by u and u^* the obliquity of a given ray, or pencil, at the object and at the image, we have, provided the system is *aplanatic* in respect to the conjugate points in consideration,

$$\frac{\sin u^*}{\sin u} = \frac{n}{n^*} \cdot \frac{1}{\mathrm{N}} .$$

From these two equation results

$$\frac{\delta^* \sin u^*}{\delta \sin u} = \mathrm{N},$$

or

$$\delta^* \sin u^* : \delta \sin u = \mathrm{N} : 1.$$

The terms of the left-hand side of this proportion are *approximate* expressions of the relative parallactic displacement of the consecutive planes in the projection of the solid object and of the solid image along the oblique ray in question. It is thus seen that these displacements retain approximately the ratio of the amplification, the loss of obliquity at the image being just balanced by the extra increase of the axial distances there.

depends *solely* on the manner in which the impression of the *depth* is conceived (conformable or unconformable to the true depth), and is entirely independent of the manner in which the aspect of an object, in regard to its lateral dimensions, may be changed in observation. Therefore, any projection which affords right-eye perspective in regard to the solid image of the Microscope, will always afford right-eye perspective in regard to the object likewise, *et vice versâ.* Hence the following conclusion:—

> The image of an object, which is delineated by a pencil inclined to the *right* hand at its *emergence* from the ocular, will always yield right-eye perspective *of the object*, and the other image left-eye perspective, in *orthoscopic* vision.

All rays which have been gathered by the objective must, at their final emergence from the ocular, pass through the image of the objective's clear aperture, which is projected by all subsequent lenses. This is the Ramsden circle, visible above the eye-piece. The right-hand portion of any emergent pencil will be transmitted, therefore, by the right-hand half of the Ramsden circle, the other portion by the other half. The above inference may therefore be expressed thus:—

> The character of right-eye perspective in orthoscopic vision *always* adheres to that image which is admitted to the observer's eye by the right half of the Ramsden circle, and *vice versâ.*

According to the foregoing deduction, the perspective character of the projections which are obtained with incident pencils of opposite obliquity, does *not* directly depend on the rays having entered the right or the left half of the objective. The result is found to be independent of this. In fact, the pencil r, which gives the perspective of right-eye vision, in comparison to the pencil l, may be conjugate to (or the continuation of) the incident pencil R or L. Both cases are equally possible. The first case is met with, when the entire cone of rays emanating from any point of the object is transmitted through the optical system without inversion; the other case, when there is an inversion of the pencils of light in their passage to the conjugate points of the final image. The obvious criterion of the former is an erect position of the Ramsden circle, and of the latter an inverted position in regard to the objective's clear aperture, which is depicted by the said circle. My deduction implies, therefore, this general inference:—

> Right-eye perspective (in regard to orthoscopic vision) adheres to the image projected by the right-hand part *of the objective,* whenever the Microscope transmits the delineating

> *pencils* uninverted, or whenever the *Ramsden circle* is an erect image of the aperture; and right-eye perspective is afforded by the image from the left-hand half of the objective, whenever those pencils at their emergence from the ocular are inverted, or the Ramsden circle appears as an inverted image.

This consideration has had nothing in view hitherto but the different perspective characters of those *partial* images which may be obtained in any *monocular* Microscope from opposite portions of the objective or from opposite halves of the Ramsden circle. Let us now suppose any kind of *binocular* arrangement, by which two images of equal amplification and similar position are projected at the same time, so as to be viewed with both eyes. All the foregoing propositions must apply then to both these images at once without any restriction or modification, because all conclusions hold good for every arrangement of the optical system, whatever may be the number of lenses, or prisms, or mirrors. In order to obtain true stereoscopic impressions of an object in *binocular* vision, it will be *necessary* and *sufficient*, therefore, that the right eye be affected by the rays from the right-hand half, and the left eye by rays from the left-hand half of *that* Ramsden circle which is depicted in front of each eye, the opposite halves remaining ineffective; pseudoscopic vision will be obtained from the opposite arrangement, of course.

Thus the proposition pointed out at the commencement of this paper is shown to express the true and general condition of either orthoscopic or pseudoscopic vision with the Microscope.

In the ordinary binocular arrangements the rays which are transmitted by opposite halves of the objective, are admitted to different oculars separately. In this case, *one* half of the full Ramsden circle only is depicted at the back of each eye-piece, the other halves being stopped-off by interposed prisms. The effect will be orthoscopic, therefore, whenever the two semicircles appear in the position O (Fig. 36), and it will be pseudoscopic whenever they appear in the position P. Whether or not, under these circumstances, orthoscopic action will require crossing-over of the rays from the right-hand half of the objective to the left eye-piece, and *vice versâ,* depends solely on the manner in which the delineating *pencils* are transmitted through the system, or the aperture of the objective is projected. In a Microscope with non-erecting ocular the emergent pencil is now inverted with reference to the incident pencil. In the Wenham and the Nachet binoculars, consequently, crossing-over *is* required, because the inversion of the pencils is not changed by two reflections, and the Ramsden circle represents still an inverted image. If the delineating pencils have been reflected an *even number* of times in the same plane, it will be necessary for the rays to cross; on the contrary, if they have been reflected an odd number of times, it is not only unnecessary, but is destructive of orthoscopic effect, provided ordinary (non-erecting) eye-pieces are applied. Hence in Stephenson's binocular such crossing-over is *not* required (and would give pseudoscopic effect) because the reflecting prism makes the final emerging pencils by one reflection conformable to the incident pencils, and projects the aperture of the objective as an erect image (the plane of the two axes being considered only).

According to general dioptrical propositions, uninverted transmission of the pencils from the object to the image (and erect position of the Ramsden circle) is always *allied* to an erect image, and *vice versâ.* The position of the microscopical image (whether erect or inverted) may therefore be used in order to determine the conditions of orthoscopic or pseudoscopic vision. It ought to be borne in mind, however, that this criterion does not indicate the *causa efficiens* of the one or the other kind of action, but rather an accessory indication only.

As to those other binocular arrangements by which two images are produced without a geometrical division of the rays from the opposite halves of the objective, each eye-piece projects a full Ramsden circle, and thus simultaneously embraces an image with both right and left eye perspective. Of course these are non-stereoscopic in themselves, as is the case, for instance, with Powell and Lealand's arrangement, and with that device which was pointed out by Mr. Wenham in 1866 and applied in the author's stereoscopic ocular. With binoculars on such a principle either kind of stereoscopic action may be obtained at pleasure by *suppressing* one-half of each Ramsden circle. Suppressing, by suitable diaphragms at the exact plane of the Ramsden circle,† the inside halves (the right half for the left eye and the left half for the right eye) of both circles, orthoscopic effect is produced; pseudoscopic, when the outside halves are stopped off.

Moreover, the difference of perspective between an image projected through the centre of the aperture (or of the Ramsden circle) and another image projected through an excentrical portion, will be half that difference which is obtained from opposite excentrical portions, but will retain the same character still. For obtaining stereoscopic action with binocular arrangements of the kind here referred to, it will be sufficient, therefore, that *one* Ramsden circle only be half-stopped, the other being left active in its full extension. Orthoscopic effect (though with less difference of perspective) will

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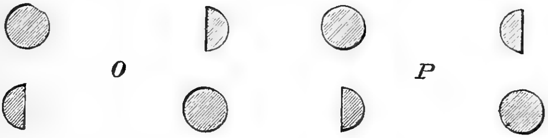
† This condition is necessary for obtaining the bisection of the emergent pencils from *all* points of the field at the same time. Diaphragms at any other plane (where the emergent pencils have not a common cross-section) would, of course, encroach more or less upon the field of vision. If, however, the above condition is fulfilled, *there cannot be any encroachment on the field.*

always arise, if the right half of the left circle *or* the left half of the right circle is suppressed. We have, therefore, two other arrangements for either kind of stereoscopic effect, which are equivalent to O and P of Fig. 36, respectively—as represented in Fig. 38.

Fig. 38.



In view of the considerations here advanced, it must be quite immaterial in the action of the binocular arrangement how the rays are brought to the oculars and whether these oculars yield erect or inverted images. And as the only conditions of stereoscopic vision—two images of opposite perspective projection—are fulfilled by the method pointed out above, exactly in the same degree as with binoculars on the ordinary system, there is no rational ground for presuming that the effect must be inferior in regard to the *reality* of orthoscopic or pseudoscopic impressions. In fact, a few experiments with the binocular eye-piece described in the paper quoted above (or with any similar arrangement) will prove the validity of the principle here developed.

V.—*On a Species of Acarus, believed to be Unrecorded.*

By A. D. Michael, F.L.S., F.R.M.S.

(*Read* 9*th March*, 1881.)

Plate IV.

The singular creature which forms the subject of this paper belongs to the genus *Dermaleichus* (Koch) *Analges* (Nitsch), but will not fit into any of the five genera, or sub-genera, into which Robin has divided the group. I do not attempt to create a new genus or sub-genus for it at present, because I think that our acquaintance with the animals is too limited to make it desirable to attempt exhaustive generic descriptions.

I found several females, and one male, parasitic upon the cormorant, at the Land's End, Cornwall, in the autumn of 1879, but this male presented such remarkable features that I feared it might be a deformed specimen, and was afraid to describe it from a single example. I could not obtain another, and therefore deferred noticing the species until 1880. In the autumn of the latter year I got some more cormorants, in the same place, and obtained more males; they were all alike.

The great leading feature, which is so striking in the male of this species, and in which it is entirely different from every other *Acarus* that I have seen, is, that the left leg of the second pair is conspicuously larger than its fellow on the right side, has a totally different tarsus, and is supported by a different and more powerful epimeral * and sternal arrangement, so that the two sides of the anterior half of the creature are unequal. This occurs in the male only, and I have no doubt that the enlarged leg is used for holding the female during coition, although I have not been able to find a pair in that act, as one usually may in most species of the genus.

It is frequent, and even usual, among the *Dermaleichi*, for one pair of legs, in the male, to be largely developed, for the purpose of holding the female, and little, if at all, used at other times. The enlarged pair of legs is generally the third, occasionally the first. I am not aware that I have before seen the second pair so developed,

EXPLANATION OF PLATE IV.

Fig. 1.—*Dermaleichus heteropus*, male × 95.
" 2.— " " female × 95.
" 3.— " " under side showing the epimeral and sternal skeleton shaded dark, and exhibiting the difference on the two sides.
" 4.— " " one of the suckers highly magnified.

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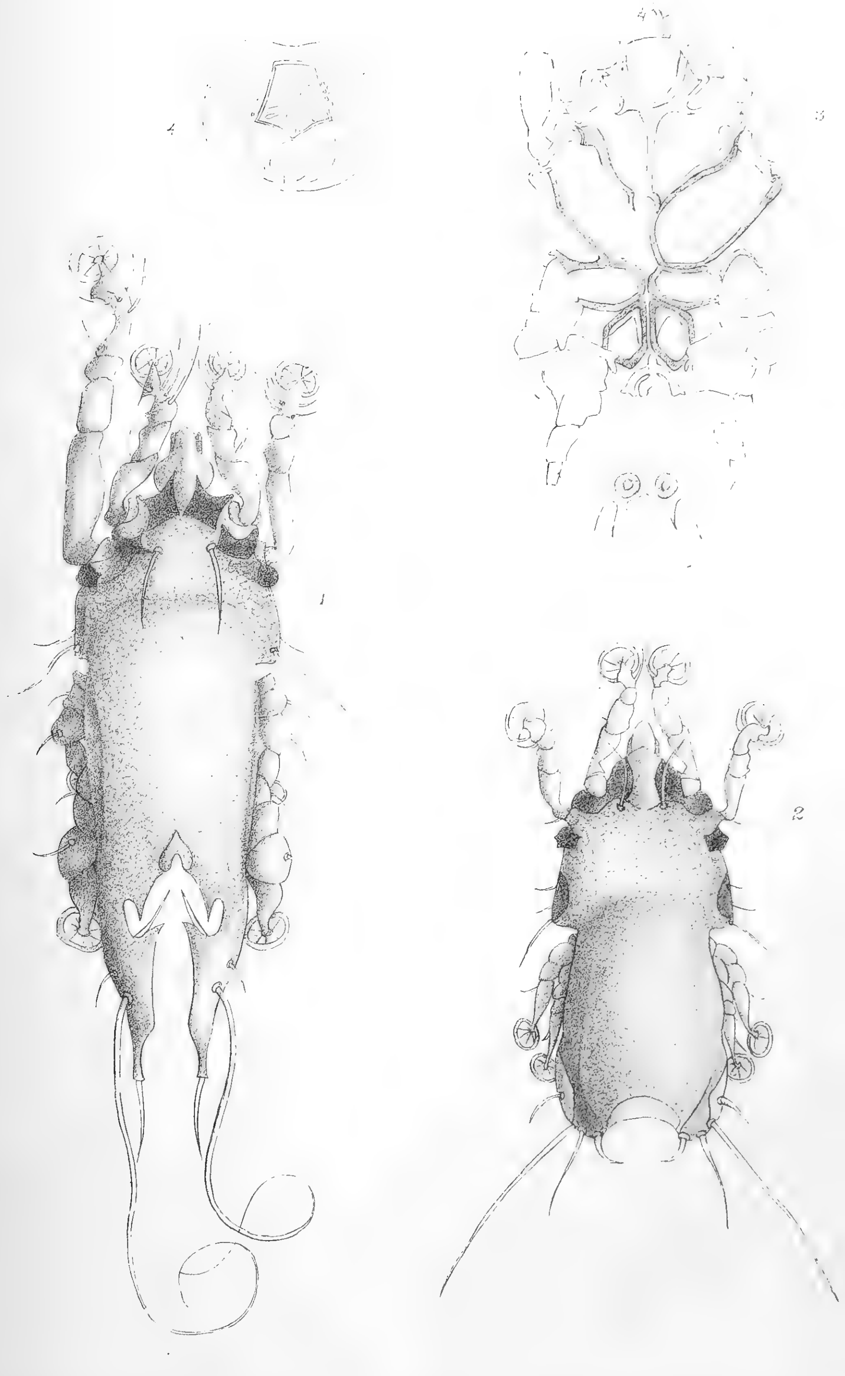
* I use the word epimeron in deference to Professor Robin and M. Mégnin, who have employed it for the part spoken of.



A. D. Michael ad nat. del.

West, Newman & Co. lith.

Dermaleichus heteropus.

and I most certainly have not ever seen or heard of one leg being so developed without its fellow on the other side. It seems to me that to find an analogy one must travel into a different order of created beings; and that it is in the Crustacea and the single, enlarged, copulative antenna of some of the *Entomostraca* that the closest resemblance will be found.

Another somewhat striking feature of the species is the extreme massiveness of the chitinous strengthenings of the dermal skeleton; those round the anterior dorsal margin form a chitinous collar, thickest between the insertions of the legs, and thinnest opposite to them. The sternal and epimeral skeleton of the ventral surface, particularly in the male, are also more powerful than I remember in any other species. I have, however, remarked that the chitinous strengthening is usually stronger in species parasitic upon aquatic, and particularly marine birds, than in those found on terrestrial ones. One is inclined to ask the reason of this, and the question is not very easy to answer; but I am inclined to think that the rougher life led by the host, and the more constant exposure to alternations of wet and drying, might be too much for the softer bodies of the species found upon our sparrows and song-birds.

Another characteristic of this species is the remarkable length and size of the caudal projections in the male; it is somewhat singular that the nearest approach to this, and to the general shape of the present species, is in *Dermaleichus starnæ*, a species found by Professor Canestrini of Padua; also on aquatic birds (*Larus ridibundus, Starna fluviatilis,* &c.).

I believe the species to be unrecorded, and if so, propose to call it *Heteropus.*

Description.

Average length ♂ about	1·1 mm.
„ „ ♀ „	·75 „
„ breadth, both sexes, about	·42 „

The lengths are measured from the centre of the posterior margin of the body to the tip of the front outstretched tarsus.

The colour of the skin, in both sexes, is the brownish white usual amongst the *Dermaleichi*; the skin is finely plicated into folds on the ventral, and short, somewhat vermiform markings on the dorsal, surface.

The notogastral plate is somewhat chitinized, and light brown. Masses of chitine which form the outer termination of the epimera appear to lie on each side of each leg of the two front pairs, are very dark brown, and, from their great development, are conspicuous objects, the whole anterior margin of the creature, except the rostrum, appearing to be strengthened by a great chitinous collar. The legs are wholly chitinous.

Male. Fig. 1.

The shape, excluding the caudal projections, is roughly pentagonal, the rostrum, which is small, forming the apex, and the two anterior sides being almost at right angles, so that the dorsal surface, anterior to a transverse line drawn behind the insertions of the second pair of legs, forms a right-angled isosceles triangle, which occupies about a quarter of the length of the body. Behind this is a sharp indentation, having the anterior side oblique, and the posterior almost rectangular. Behind this indentation the body attains its maximum breadth, and runs with parallel sides until it reaches about half its length (not including the caudal projections); then there is another indentation, rather deeper than the first. The body does not widen again posterior to this, but narrows slightly and gradually to the hind margin, the lateral margin being slightly undulating. The posterior margin fades, without any sign of demarcation, into two great caudal projections, which are half as long as the body, and the two, at their insertion, occupy the entire width, so that the hind margin appears to be cleft with a deep triangular notch. The outer edges of the caudal projections curve inwards, and end in sharp, strong points; the inner edges, posterior to the triangular notch, are nearly parallel to the long axis of the body, but, at the point of junction of the triangle and straight side, there is a longitudinal indentation, at the anterior end of which is a strong, brown, chitinous spike, projecting backward and outward, formed by the prolongation of the edge of the chitinous notch; and at the posterior end is a longer, thinner, white spike projecting forward and inward.

The whole notogaster is covered with a chitinous plate (not very thick), which commences behind the epimera of the second pair of legs, and coalesces with the caudal projections, which are wholly chitinous.

The first pair of legs are short (about three-eighths of the length of the body), and are only separated from the rostrum by one of the chitinous masses above spoken of. The coxa is short, the trochanter large and powerful, the femur shortish and cylindrical, the fourth joint short and trapezoidal, the tarsus large, turned outward, and having a strong spike from its posterior outward angle, turned backward and outward. The sucker on this, and all the other legs, is very large and complex. (Fig. 4.)

The second pair of legs constitutes, as above stated, the leading feature of the species, being different on the two sides; that on the right side attains the same distance beyond the rostrum as the leg of the first pair, from which it only differs in the trochanter being longer and thinner, and the tarsus being without the spike. The leg on the left side is more than half as long again as that on the right, and more than proportionately stouter; it reaches much in front of all the other legs, although usually carried obliquely, so as to cross in front of the rostrum. It is about the same general shape as the leg on the other side, but the femur is longer in proportion, and the tarsus is quite different, having a strongly concave, instead of a convex outer edge, and being thinner and more chitinous, but increasing suddenly at the distal end, instead of coming to a point.

The two hinder pairs of legs are distant from the front pairs, so short as not to reach beyond the body, and about equal-sized. They are only visible from their great thickness, as they are set under the body. Each of the first three joints of these legs is greatly wider than its length. The tarsi are curved inward.

The epimera are different on the two sides, that of the enlarged leg having a special provision to support it. From the chitinous block on each side of the rostrum a very short branch extends to a sternal ridge. The epimeron of the right side is not anchylosed to this ridge; that on the left is. The epimeron on the left side is the strongest, and is anchylosed to that of the first pair, whereas that of the right side is free. The epimera of the second, third, and fourth pairs are joined on both sides. The epimera from the two sides nearly meet at the median line of the body, but are not joined.

The penis is short and broad, and is supported by a horseshoe-shaped sternite, with a central point projecting forward. There is one pair of anal suckers.

Hairs.—An extremely long, flexible hair, almost as long as the body, is attached to each of the caudal projections about a third of the distance from the tip; and another, rather shorter and finer, still nearer to the distal end. There is a strong hair near the posterior angle of the wide part of the body, a pair on the dorsum of the cephalothorax, numerous hairs on the tarsi, and a few scattered ones on other parts of the legs and body, particularly the under side.

The Female (*reproductive*). Figs. 2 and 3.

The anterior part of the body is much like that of the male, but the chitinous collar is even heavier. The abdomen is not so long as in the male, and not so much diminished posteriorly. The chitinous notogastral plate does not reach the hind margin, and there are not any caudal projections, the hind margin being transparent, but strengthened at each side by a band of chitine, which runs along the edge of the body on the ventral surface.

At the angle of the posterior and lateral margins is a curved spike; then, proceeding forwards along the lateral margin, come two very long hairs, nearly corresponding to those on the caudal projections of the male, but rather thicker and shorter; then another curved spike, and then a fine hair.

The two front pairs of legs are shorter and thinner than in the male; they are about equal in length, so that the first pair comes further forward than the second. They greatly resemble the first pair of legs in the male, except in their smaller size and the absence of the spike on the tarsus.

The two hinder pairs of legs are very different from those of the male, being set further forward, and being longer, the first three joints not nearly so thick, and the tarsi much longer and more powerful, and not curved inward. The epimera of the first pair of legs are not joined to those of the second, nor to the sternum; those of the second, third, and fourth pairs are joined. None of the epimera approach the median line of the body.

The vulva is not protected by any sternite.

Except as above mentioned, the hairs described for the male exist also on the female.

The Nymph, and Nubile Female.

These resemble the adult female, except that the body of the nymph is shorter, and that, in both, the body is softer and lighter, and the chitinous masses smaller, and that there are not any chitinous ridges joining the epimera of the second pair of legs to those of the third.

The creature was found parasitic on the cormorant (*Phalacrocorax carbo*), and is not common.

SUMMARY

OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(principally Invertebrata and Cryptogamia),

MICROSCOPY, &c.,

INCLUDING ORIGINAL COMMUNICATIONS FROM FELLOWS AND OTHERS.*

ZOOLOGY.

A. GENERAL, including Embryology and Histology of the Vertebrata.

Development of the Graafian Vesicles.†—M. O. Cadiat comes to the conclusion that in both viviparous and oviparous vertebrates the nutrient yolk is not produced by the cells of the ovisac, but by a thick homogeneous membrane which invests the yolk, and which is analogous to the vitelline membrane of the Mammalia. He thus finds himself in agreement with such observers as Gegenbaur and Waldeyer. In the oviparous forms, the epithelium of the ovisac is reduced to a single layer of cells. The author recommends the cat as a most suitable animal for the study of the development of the ovoblasts.

Development of Parrots.‡—Dr. M. Braun has his third and fourth contributions on this subject; in the first he deals with the connections between the dorsal medulla and the intestine in birds. He is now convinced that there are three separate points at which this connection obtains. In the young embryos of ducks, in which there were from six to eight protovertebræ, the first point of connection obtains in front of the terminal ridge, and this one is very narrow. The floor of the medullary tube is continued ventrally into a funnel-shaped passage which opens behind the endoderm; in older embryos nothing is to be seen of this passage. The second communication is formed by the endoderm becoming raised dorsalwards in the middle line, and finally coming into connection with the medullary tube by means of a relatively wide orifice. This too becomes closed, and as the tail appears, a

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* The Society are not to be considered as responsible for the views of the authors of the papers referred to, nor for the manner in which those views may be expressed, the main object of this part of the Journal being to present a summary of the papers *as actually published*, so as to provide the Fellows with a guide to the additions made from time to time to the Library. Objections and corrections should therefore, for the most part, be addressed to the authors. (The Society are not intended to be denoted by the editorial " we.")

† Journ. Anat. et Physiol. (Robin), xvii. (1881) pp. 45–60 (3 pls.).

‡ Verh. Physikal.-med. Gesell. Würzburg, xv. (1881) pp. 120–3, 173–5.

third is seen in its neighbourhood; the post-anal enteron, which primitively has no communication with the medullary tube, obtains one by the latter bending down around the hinder end of the notochord. Later on, this connection also disappears, and the post-anal enteron becomes absorbed. Similar observations are recorded as having been made on various other birds, but the author refrains for the present from any distinct generalizations.

In his second (4th) paper, Dr. Braun states that as the post-anal enteron is absorbed, a circular constriction is developed vertically to the long axis of the tail; this becomes gradually nipped off, and forms a knob of tissue, which is connected by a narrow stalk with the true body of the tail; this decreases in size, and at last consists only of a small collection of ectodermal cells.

The notochord undergoes a special set of changes at the tip of the tail; the hinder end is, in embryonic parrots, long persistent at a lowly stage of development; there is in it a cord of rounded cells—the notochordal rods. In a number of mammals examined the same structure was detected, and found to constitute a body homologous with the caudal knob of birds just described. These observations lead to the conclusion that, in mammals as well as in birds, the notochord is, so to speak, too long; no vertebræ are formed around its hinder end. In the Amphibia (Urodela at any rate) the chorda would seem to be too short, if the observations of Flesch and Fraisse are correct.

Epidermis of Salamander.*—Dr. Pfitzner, previously the author of a dissertation on Leydig's cells in the stratum mucosum of the larva of the spotted salamander, now publishes a detailed review of the epidermis of this animal. In accordance with Flemming, he first sets forth the excellence of the salamander as a subject for the histologist (to whom it should be no less valuable than the frog to the physiologist), and gives a brief opening account of its breeding, with hints as to its maintenance during captivity. A further introduction deals with methods of preparation. The bulk of the memoir is occupied by two sections on (1) the larval, and (2) the adult form. In conclusion, the epidermis of the salamander, as exemplifying its class, is compared with that of fishes and the higher vertebrates from a physiological point of view.

At all periods of post-embryonic life, the epidermis of *Salamandra* includes the two usual strata. In the newly-born larva each of these is made up of but a single tier of cells, nor does the stratum corneum ever consist of more. According to our author, the same is the case with the frog (and probably all batrachians). The upper larval layer has a striated cuticular border, representing an earlier investment of cilia. As the time of metamorphosis approaches, the whole depth of the cell is gradually cornified, and the primitive upper stratum is then ready to be cast off. During the second month of larval life, the cells of the stratum mucosum appear two deep; a month later, there are three irregular tiers of these cells. In the fourth month the cells of the upper tier of the inner stratum change

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* Morph. Jahrb. (Gegenbaur), vi. (1880) pp. 469–526 (2 pls.).

their character, becoming flattened, to constitute the succeeding stratum corneum. We find this displayed after the first moult, which takes place in the earlier half of the fifth month. In like manner, a new stratum corneum arises by the transformation of the uppermost cells belonging to the stratum mucosum, before each periodical moult undergone by the perfect form. August or September is the regular time for these moults, whether they occur at other seasons or not. The growth of the salamander is slow, occupying several years.

The cells of the stratum corneum are always in close contact, without intercellular processes or passages. The general surface has no openings, except those of the large multicellular glands. The "intercalary cells" (*Schaltzellen*) of Langerhans do not constitute elements sharply separated from the other cells of this stratum, since all possible transitions exist between the two forms. When most distinct they are characterized by their greater depth, their reduced free surface, and the distance of their nucleus from the cuticular border. They are most abundant in larvæ during the first month. They are not shown by older larvæ or by adults, except in the skin over the eyes, where they are particularly numerous and conspicuous.

The cells of the polyderic (though not definitely laminated) stratum mucosum are very clearly limited from one another. Between contiguous cells run short processes directly connecting their parietal protoplasm. These processes do not interlock, but are uninterruptedly continuous from cell to cell. The spaces which they cross probably constitute a peripheral extension of the lymph-path, not separated from the serous passages of the corium. Within these spaces we sometimes find wander-cells, distinguished by their much smaller nuclei from the proper cells of the epidermis among which they push their branches.

Two kinds of elementary organs, which disappear with the close of larval life, are notable in the stratum mucosum. These are (1) the sensory structures, belonging to the lateral line, and (2) "Leydig's cells," which are probably secretory. The former are very briefly described in this memoir. Leydig's cells (termed *Schleimzellen* by Leydig himself) exist in newly-born larvæ. They are differentiated from the other cells of the stratum mucosum while this is still monoderic; afterwards they are themselves capable of division. They are recognized by their larger size and peculiarly vacuolated protoplasm. The trabeculæ limiting the vacuoles seem quite independent of the nucleus of the cell, which is central during the first month, but eventually lies near the inner parietal protoplasm. F. E. Schulze, in 1867, found Leydig's cells in the *Triton*. Peremeschko has since twice described them in the same urodele; his account is here criticized by Pfitzner. The complete disappearance of these cells at the time of moulting is very obscure.

Pfitzner could not find any nervous structures in the epidermis of the mature salamander, although a rich plexus of nerves exists in the corium. However, "it is probable that the stratum mucosum contains nerve-fibres, and that these course chiefly within the intercellular channels." He differs from Leydig in not thinking it likely that the end-organs of the larval lateral line are finally transformed into glands; rather do they seem reduced to ordinary epidermic cells. Most characteristic of the adult epidermis are its "flask-cells," so termed from their peculiar figure. These are developed periodically by the transformation of cells of the stratum mucosum. They appear contemporaneously with each new stratum corneum; they do not seem themselves capable of division. "They belong morphologically and physiologically to the stratum corneum, and have, like this, a purely mechanical function." Various interpretations touching the genesis and office of these cells, which occur also in frogs and tritons, have been suggested since Rudneff described them (in 1865). This observer found them in the frog. Langerhans afterwards detected them in the salamander, and suspected a connection between them and Leydig's cells.

Good examples of indirect cell-division, confirming Flemming's views, were found by Pfitzner in the course of these investigations. (See his figures.)

The well-known colours of the salamander are not due to the pigment of the corium, but to that of the epidermis, which is partly diffuse, partly contained in special cells (chromatophores). The origin of these cells is not known; are they truly epidermic, or have they come from the corium? There is little difference, save as to degree, between the pigmentation of the adult and of the larva. Parts which are faintly coloured in the former, as the under surface of the head, are usually without pigment in the latter. By confining larvæ, from their birth, in shallow porcelain vessels kept in the dark, as suggested to our author by Dr. Boas, less pigment becomes formed; such specimens are obviously favourable for microscopic study. The pigment-granules of the stratum corneum generally form a layer just within the cuticular border; those of the stratum mucosum more affect the upper (outer) halves of the cells in the larva than in the adult. The cell-nuclei and intercellular spaces never contained loose pigment-granules. Leydig's cells, also, showed no pigment.

The cornea, which is very unlike that of the frog, takes no share in the successive moults, but retains throughout life the characteristic structure of the epidermis of the newly-born larva. It is well supplied with intercalary cells, but has no flask-cells or cells of Leydig. The system of intercellular spaces opens freely upon its surface.

Of all parts of the body the epidermis is most immediately, constantly, and extensively related to the environment. Its passive as well as active functions are plainly, therefore, of the first importance. We are thus led to note the contrasting structures which it displays among fishes and larval amphibious vertebrates, on the one hand, and typical terrestrial vertebrates on the other. The stratum corneum in the former is represented, functionally at least, by the cuticular border of the outer tier of cells. There is an unmistakable resemblance between the soft tegumentary and alimentary epithelia; both, indeed, are exposed to a liquid medium. In the higher vertebrates we find a polyderic stratum corneum. The adult salamander, like other members of its class, here occupies an intermediate position of much interest. Apart from other structural modifications, we can at once point to their monoderic stratum corneum.

Ciliated Cells.*—How are the cilia of ciliated cells related to the neighbouring parts of the cell? By a fresh series of delicate observations, Prof. T. W. Engelmann has thrown further light on this question. A highly differentiated cilium with its appurtenances displays under favourable circumstances the following constituents:—There is, first, an *intracellular fibre* (Wurzelfaser, Wimperwurzel) whose outward end is connected with (2) the *pedicle* (Fusstück) of the cilium; this pedicle is separated by (3) an *intermediate segment* (Zwischenglied) from the cilium proper, resolvable into (4) a proximal *bulb* and (5) a terminal *shaft*.

That the intracellular fibres really exist and are not folds of a membrane or otherwise due to optical illusion, can now be demonstrated. They are best seen in cells of the intestinal epithelium of lamellibranchs (Cyclas, Anodon). They traverse the soft substance of the protoplasm, pursuing a parallel course through its outer portion and converging more deeply to form a conical bundle, from whose apex proceeds one long originating fibre (Stammfaser) which thins out so as to be no longer measurable until its pointed end disappears. Although this trunk-fibre may approach or run close beside the nucleus, there is no reason for supposing that it unites with it. The convergence of the fibres is in some cells less marked, and the presence of a trunk-fibre is then doubtful. In others, again, a trunk-fibre seems absent; here the fibres do not converge, but remain quite parallel to one another, while the inner extremity of each fades away into the surrounding protoplasm. When the fibres are numerous, the protoplasmic interspaces which separate them, near the outer portion of the cell, are about equal in diameter to the fibres themselves, or less than $0 \cdot 3\ \mu$. The separate fibres are smooth or but slightly varicose; yet they sometimes become very regularly granulated under the influence of reagents or even spontaneously, in the act of dying. Under high amplification each fibre remains homogeneous. Nussbaum was certainly wrong when he viewed the intracellular fibres of the intestinal epithelium of Anodon as made up of two apposed anatomical elements, the one elastic and strongly refracting, the other contractile and nearly identical with the adjoining substance of the cell. By using solution of bichromate of potash (4 per cent.) or common salt (10 per cent.), Engelmann, after careful teasing with fine needles, was able to separate *en bloc* from the rest of the cell the entire fibrous apparatus of the cells in question. Such aggregates or quite isolated fibres, the result either of art or accident, serve well to display the connection of the fibres with their corresponding cilia and pedicles. Engelmann also figures very clearly *in loco* the intracellular fibres of the long cylindrical cells of the gut of Cyclas. These cells, with their fibres and cilia exceptionally conspicuous and few in number, remind us of caliciform secreting cells; they, indeed, represent an intermediate phase between these and ordinary cells.

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* Pflüger's Arch. Physiol., xxiii. (1880) pp. 505–35 (1 pl.).

The pedicles of the cilia, though *in directum* with the distal ends of the intracellular fibres, are not mere enlargements of these fibres. Engelmann expressly states that the relation between the fibres and pedicles is one rather of contiguity than of continuity. Nor are the pedicles simple prolongations of the cilia; they are specialized parts, having their own optical and chemical properties, differing both from the fibres and the cilia proper. The pedicles rest upon the outer portion of the protoplasm or are sunk just beneath its surface. They lie close to each other, with intervening parallel streaks of soft cell-substance, or they constitute by their lateral union a membrane-like mosaic, also termed the operculum. The homology of this operculum with the cuticular border of certain intestinal cells is obvious. That we have here a true mosaic of bacilliform elements, a genuine plinth to the cilia, and not a sieve through whose pores the cilia pass (as wrongly stated by Eberth and by Marchi), is now shown by the concurrent testimony of Eimer (1877) and Engelmann. In all ciliated cells which possess these pedicles, their relation towards the cilia seems the same. The pedicles exhibit single refraction, the fibres and cilia double refraction. Eosin stains strongly alike the fibres and cilia, but has less effect on the pedicles. Methyl-green also stains equally, though weakly, the cilia and their fibres; it acts much more readily on the pedicles. Anilin-blue, indulin, carmine and picrocarmine, especially the first, colour the cilia but faintly in comparison with the tinge which they impart to both the intracellular fibres and pedicles.

The intermediate segments, which very generally separate the pedicles from their cilia, are easily seen in many fresh cells. If not so, reagents can show that the threshold of the cilium differs from the cilium proper. Each segment is usually less than $0 \cdot 5\ \mu$, very seldom $2\ \mu$ long. Its refractive index scarcely exceeds that of water. In such cells, careful profile views reveal between the pedicles and cilia a clear (protoplasmic or secreted) border with very delicate parallel striæ. The segments do not display double refraction. They are much softer and more destructible than either the cilia proper or the pedicles. When cilia are cast off they usually give way so that one portion of the segment clings to the cilium proper, another to the pedicle; but the whole of the segment may remain attached to either.

The bulb, often well seen in isolated cilia, refracts somewhat more strongly than the shaft. When best displayed, it appears as a fusiform or spherical thickening about $0 \cdot 5\ \mu$ long. From what has been said it is plain that between the intracellular fibres and the shafts of the cilia three layers may be distinguished. These are respectively constituted by (1) the pedicles, (2) the intermediate segments, and (3) the bulbi. Thus the first and third layers may be very clearly separated by the much fainter intermediate layer.

The shaft of the cilium is directly continuous with its bulb, like which it shows double refraction. In no case could Engelmann distinguish a cuticular sheath with protoplasmic contents, as described by Simroth. Frequently the apices of the shafts become regularly knobbed after treatment with dilute solutions of chromates or Müller's fluid.

As touching the differences among ciliated cells, there is much need for additional observations in so wide a field. The presence or absence of fibres and pedicles, should such distinctions be confirmed, offers a basis for primary divisions. "In the simplest cases the cilia appear as direct prolongations of the protoplasm, or at least they arise immediately from its superficial layer: thus is it with many of the lowest unicellular organisms, as the zoospores of the lower plants, the Flagellifera, the Ciliata, also in many embryonic as well as definitive epithelial cells of the lower and higher Metazoa." Yet in Vaucheria, as Strasburger has shown, the hyaline cortical protoplasm of the zoospore contains minute radiating rods, each of which subtends a cilium. In some ciliate Infusoria peculiar and more complex conditions present themselves. In the higher animals with well-specialized cilia we not only find, on comparing different cells, diversities as to the number, size, and direction of the intracellular fibres, but the chemical or optical behaviour of these fibres varies, even where we meet with no obvious distinctions of texture. The several arrangements of the cilia must also be considered. The cells of lamellibranchs and a few vertebrates have hitherto been most studied. Engelmann here figures and describes the two distinct kinds of ciliated cells found in the intestinal epithelium of the former; he has further studied the cilia of the oral tentacles of the mantle, and, especially, of the gills. He devotes part of his memoir to extending and correcting the previous results of Posner. Among rotifers, e. g. Brachionus, we see on a splendid scale an arrangement of the cilia in parallel series, inclining obliquely to their planes of vibration, similar to the more minute display of three distinct systems on the respiratory cells of many bivalves. In vertebrates the ciliary intracellular fibres are not easily seen. Nevertheless, Engelmann figures them as they appear in a cell from the nasal lining of the frog. An exceedingly delicate striation could also, after careful treatment, be detected in cells from the windpipe of the rabbit. In many cases where no fibres have yet been discovered they may eventually be proved to exist; their obstinate invisibility being either the result of extreme fineness or of feeble differentiation from the rest of the protoplasm.

The physiological connection of the intracellular fibres with their cilia is discussed by Engelmann in the last section of his present memoir. That the fibres are not contractile, that they are still quiescent while the cilia display active movements—seems indubitable. Stuart erroneously interpreted, as Engelmann here explains, the apparent displacements of the nuclei in the ciliated cells of the velum of larval Eolids, ascribing them to changes of position undergone by the fibres in question. Besides Stuart and Nussbaum (see E, pp. 527–529), if we except a short and probably faulty account by Bonnet, no other observer among the host of microscopists who have seen cilia in action has noted contemporaneous intracellular movements. In vain has Engelmann sought to detect such movements, or to excite them by experimental means. Laborious and varied researches, directed to this end, have always yielded to him negative results. Since, then, the fibres are non-contractile, can they (he asks) be nervous? Such a view is plausible and may be true of the fibres which supply the complex marginal lashes of Stylonychia, not to speak of other Infusoria, but can scarcely hold good of ciliated cells in general. In spite of a certain agreement, the differences between intracellular ciliary fibres and true nerve-fibrils are too striking to admit of such an interpretation. Doubtless the origin of the cone of fibres from one trunk-fibre and the way in which they incline towards the cilia offers a very tempting explanation of the isochronous motions of the latter. But do we ever find axis-cylinders which, like these fibres, may be stiff, show double refraction and obstinately resist various strong chemical solvents? Neither may we conclude that the fibres act as mechanical supports to the cilia; they are too loosely connected with these, and in the majority of cases too lax and perishable for such a purpose. Most likely is it that the fibres contribute to the nutrition of the cilia, supplying the materials needed for the discharge of their function and the renewal of these active and short-lived filaments.

Finally, Engelmann refers to the presence of a fibrous structure in various non-contractile secreting cells. Most notably do the cells lining the ducts of the spinning glands of the silkworm, as described by Lidth de Jeude,* resemble in this respect ciliated cells by their optical no less than their more obvious structural characters. The discovery by Max Schultze of filaments in the outer moiety of the inner segments of the retinal rods and cones also aids him in rebutting the assumption that the intracellular fibres of such structures can subserve a merely mechanical office.

We have said little of the reagents used by Engelmann in these refined observations. To those who study methods as well as results, his essay is indispensable. His recommendations of green light and of an apparatus which guards the eye from disturbing rays are too valuable in practice to be neglected.

Central Nervous System of Reptiles and Batrachians.†—Dr. J. J. Mason deals with the form of the spinal cord, and especially that of its enlargement; the nuclei of the nerve-cells, and variations in their shape, size, &c., in the same individual; the number of ganglionic bodies in the spinal cord, and their relations to the roots of the spinal nerves, and the difference, if any, which may be determined by sex. After stating the methods of preparation of his sections, Dr. Mason gives the following as the result of very extended examinations of a large number of sections of the spinal cord of the frog and different reptiles.

1. The central canal of the spinal cord of frogs is more nearly cylindrical in shape than has been generally supposed. The oval

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* See this Journal, ii. (1879) p. 297.

† 'Journ. of Nervous and Mental Disease,' Chicago, 1880, 8 pp.; Amer. Natural., xv. (1881) p. 50.

contour is not seen in cross sections below the second pair of nerves, when the membranes are not removed before hardening.

2. The nuclei of the large nerve-cells are more generally oval in form than are those of the smaller cells.

3. The nerve-cells of the crural enlargement are as abundant as those of the brachial enlargement, if not more so. Their nuclei are larger, as are also the surrounding masses of protoplasm or cell bodies.

4. No difference in structure can be made out in the upper portion of the cord, corresponding with the sexual function in the male. The long-continued and violent tonic spasms of the anterior extremities must be explained by local hyperæmia influencing the same structure as those which exist in the female.

5. The relation which is generally believed to exist between the so-called motor-cells and the inferior (anterior) roots, can be demonstrated in the frog more readily than in any other animal.

Cellular Irritability.*—M. Richet gives the following synopsis of the effects of stimuli on simple animal and vegetable cells. (1) Oxygen is necessary, and there is consumption of oxygen during the life of the cellule. (2) The intensity of movements grows with the temperature, up to 40° C.; above 40° the movements disappear. (3) Neutral solutions slightly alkaline are favourable; acid solutions are fatal. (4) All change of condition is a stimulant to the cell, and consequently provokes its contraction. (5) But this change of condition must be abrupt, for if gradual, it does not provoke reaction. (6) The reaction from the stimulus is not sudden, but there is a period of "latent excitement" which diminishes in proportion to the intensity of the excitation. (7) Weak stimulation, powerless when isolated, becomes effective when frequently repeated at short intervals

Epithelium of the Human Stomach.†—Dr. Stöhr comes to the conclusion that (1) the mucous-gland-cells are not destroyed during the secretion of mucus, but that they, like the cells of the gastric epithelium, are persistent; (2) that the so-called complexes of marginal cells are the peripheral protoplasmic portions of the mucous-gland-cells which are not converted into mucus. The author's observations appear to have been made on a stomach which was removed from a criminal half an hour after death. The organ was completely empty; there was but a small quantity of mucus in it, and the reaction that it gave was acid. Sections were placed in Müller's fluid, chromic acid (·5 per cent. sol.), strong spirit, and a one per cent. solution of osmic acid. The best results were obtained with the first of these.

Influence of the Mode of Preparation on the Movements of Protoplasm.‡—It is well known that in preparing sections to exhibit the motion of protoplasm in the living cell, it may often be noticed that the first effect of the section itself is entirely to arrest all movement,

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* 'Rev. Scientifique.' See Amer. Natural., xv. (1881) p. 59.

† Verh. Physikal.-med. Gesell. Würzburg, xv. (1881) pp. 101–20 (1 pl.).

‡ 'Flora,' lxiv. (1881) pp. 8–14, 24–30.

which then recommences after a short time, and is rightly regarded as a continuation of the original movement. Dr. C. Delmecke has investigated the conditions under which such secondary movements may be regarded as normal, i. e. recommencements of movements of the living cell, or as abnormal, i. e. movements set up anew in the injured cell; and has come to the following general conclusions:—(1) Both normal and abnormal movements may be observed in cells under the conditions named; (2) the latter are derived from the former, and occur when organs are wounded, when they absorb much water, when they are prepared in water, and when frozen organs are thawed; (3) currents may set up in the protoplasmic utricle independent of those in the bands of protoplasm, but may pass over into the latter.

Passage of Red Blood-corpuscles into the Lymphatic Circulation.*—This phenomenon has been observed to have taken place in the lymphatic duct and in the lymphatics; the one case being explicable by regurgitation of blood through the imperfect valves at the upper end of the duct, the other by diapedesis through the walls of the vessels. Red corpuscles have also been made by M. Laulanié to pass into the lymphatics of a tributary of the carotid artery in the horse by ligature of the jugular vein. In twelve hours after the operation the first are seen under the Microscope; four hours later their number is equal to that of the colourless corpuscles; at the fortieth hour the number attains an average maximum (the number of red corpuscles is now three times that of the sixteenth hour), which is afterwards maintained, subject to temporary oscillations. The number of the corpuscles is also increased by feeding; at this time the flow of lymph increases rapidly, and the proportion of red corpuscles suddenly becomes doubled, that of the white ones remaining constant; the original proportions are resumed when mastication ceases. What influence the nervous system exercises in the phenomenon still remains to be decided.

Relations between Muscular Activity and Breaking down of Material in the Animal Body.†—Experiments relating to this subject, carried out by C. Kellner on a horse eleven years old, have yielded the following main results:—(1) In producing kinetic force an organism necessarily uses up alimentary and histological materials. (2) Non-nitrogenous matter is seized on for this process, and when this is insufficient or is exhausted, organized albumen is broken down. (3) The latter process can only be stopped by increase of food, especially of non-nitrogenous compounds. Even large supplies of albumens cannot stop this loss when the sum-total of the food-elements is insufficient for the needs of the body. Such loss in the case of beasts of draught and burden is usually to be met by use of non-nitrogenous foods. (4) It is probable that a more abundant circulation of albumens is necessary during work than the minimum amount required during rest, owing to the increased need of oxygen

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* Comptes Rendus, xci. (1880) pp. 1082–4.

† Naturforscher, xiii. (1880) pp. 409–12.

in the former case. In this case the minimum quantity of albumens required must vary with the intensity of the labour. (5) An organism which has ample means of subsistence, and is therefore in a constant condition of efficiency, can utilize in profitable exertions of strength more than half the latent force contained in the digestible non-proteids supplied to it.

Discrimination of Species.—In the introduction to his lately published 'Pterophoridæ of California and Oregon,' Lord Walsingham observes: "The manner in which my journey was performed has brought into some prominence the very interesting but perplexing question of the value of apparently specific differences. In consequence of my changing the collecting ground every two or three days, with a few exceptions, throughout the season, by short marches of from fifteen to thirty miles a day (moving northwards in the summer of 1871 and southwards in the spring of 1872), I was enabled to acquire a considerable series of specimens of several species, ranging perhaps, in some instances, over 100 or 150 miles of country, exhibiting almost imperceptibly gradual but extensive variation both in size and colour. In one or two notable instances the range of this variation would seem to include two or even three different forms, which, if they had been found without their intermediate connecting-links, would certainly have been considered distinct species; and even after a careful comparison of an extended series, it must still remain, in some cases, an open question whether they are or are not entitled to specific rank."

B. INVERTEBRATA.

Mollusca.

Structure and Histology of the Ink-bag of Sepia.*—In *Sepia officinalis* M. Girod finds the gland which secretes and the bag which contains the ink to be quite distinct from each other. The bag is formed of a wall made up of three coats; the external one is formed by loose connective-tissue fibres; the middle coat comprises a layer of transverse and one of longitudinal muscular fibres and one which imparts the silvery colour to the sac; the interior coat consists of a dense connective-tissue layer covered with a pigmented pavement-epithelium. At the posterior and inferior side the wall is invaginated to receive the gland, which is immediately in contact with the internal coat. The gland which is free and exposed to the water in front, consists of *areolæ* formed by a number of undulating lamellæ inserted upon the wall and forming oblique and anastomosing septa or *trabeculæ* across its cavity; the septa are charged with black pigment. But the essential part of the gland is an elongated conical body occupying its lower third; it is white at the apex, but towards its base gradually assumes the appearance of the black trabeculæ. The white tissue of the apex is made up of elongated transparent cells, with a large nucleus at one of their ends, resembling cylindrical epithelium; lower down in the cone the superficial cells vary from round to

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* Comptes Rendus, xcii. (1881) pp. 364–7.

fusiform, and are almost entirely occupied by the nucleus which contains one or more nucleoli; in the black tissue the cells contain black granules. The cone is made up mainly of lamellæ, varying from a mere bud-like condition at the apex to that of the fully developed trabecula at the base; they consist each of a band of connective tissue on which the above-mentioned epithelial elements are based. An irregular circular opening at the anterior and upper end of the gland transmits the secretion to the excretory sac.

Genealogy of the Ammonites.*—L. Würtemberger finds that in the first, that is, youngest whorls of the shell of *Ammonites*, the lobe-lines which mark on the exterior the points of junction of the septa, are always simpler than those of the adult chambers, often as simple as in *Goniatites;* hence they point to a derivation of the one form from the other, and species of *Ammonites* with simpler lobes are to be considered as more primitive in type. Again, branched ribs represent a state derived from simple ribs, but the branching may go so far as to produce from each two ribs simple like the first. Spines and projections first appear in the younger whorls; therefore, the species which possess them are further evolved than those which do not. Species which have no ribs but have spines, carry their spines in the same positions on the shell as they would if they had ribs, e. g. at the place corresponding to the bifurcation of the rib, &c.; therefore the rib-less is derived from the ribbed condition. The occurrence of a marginal furrow running on the outside of the shell in a position corresponding to the siphon within, and serving to protect this organ, is a more highly evolved condition than that with a plain margin, and the addition of spines to this region with the same protective object must be considered as marking a further step in advance. Now, when these spines, in obedience to the law of occurrence of the ancestral condition, appear in the younger segments of the disk-like shell, they occupy so inconvenient a position with regard to its growth, that a lateral deviation from the spiral form is introduced, producing such forms as *Crioceras*, *Hamites*, *Turrilites*, the latter of which, in accordance with the theory, appears quite late in the series, viz. in the chalk. The genealogy of the Jurassic Ammonites thus commences with the Liassic Planulate forms (*A. communis*, *anguinus*, *annularis*), from which are derived the *Armati* (*Aspidoceras*), on the one hand, and on the other the *Polyplocus* forms of the White Jura. The series is to be considered as monophyletic, i. e. but one chain of forms exists.

Gustatory Organs of the Heteropoda.†—From a preliminary communication from Professor Todaro, we learn that the gustatory bulbs are set in two or three rows on each side of the buccal cavity, and that in *Pterotrachea* they extend a little beyond the enlarged extremity of the proboscis. The bulbs are invested by the epithelial layer of the buccal mucous membrane, and by a cuticular layer, which is pierced by a pore at the tip. In structure they resemble the same organs in mammals; the sensory cells form a cone, and have a large

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* Naturforscher, xiii. (1880) pp. 370–1.

† Arch. Zool. Expér. et Gén., viii. (1880) (Notes et Rev.) p. 1.

vesicular nucleus; they are connected with a nerve-fibril, and the free extremity carries a long sensory hair, which traverses the canal in the cuticular layer. The bulbs beyond the proboscis have the cuticle very delicate, and the canal reduced in size, while the hairs or setæ are set in a bundle. The nerve-fibres have an elastic and very transparent sheath, and an axis-cylinder, which may be distinctly seen to be made up of fibrils. The fibre loses its sheath at the base of the gustatory organs, and the fibrils separate and, penetrating into the corpuscle, come into relation with the central portion of the gustatory cell.

"Lung" of Onchidium.*—M. Joyeux-Laffuie describes the characters and discusses the nature of the organ described by Cuvier in this animal as a lung, which lies in the walls of the mantle, and opens to the exterior at its edge behind the anus. It is formed of two lobes, right and left, united posteriorly by a narrow band containing the orifice. In section the organ is seen to consist of an irregularly areolated tissue, the cavities of which are bounded by bands of muscular tissue, but open freely into each other, and thus to the exterior. The walls of each cell or areole are lined by several layers of yellowish globular cells, containing a secretion which gives the reactions of uric acid; the innermost layer is a ciliated epithelium. The muscular layers contain the afferent and efferent vessels. The structure is essentially that of the renal tissues of Mollusca, and this interpretation of its nature is borne out by the development. In the embryo the organ appears near the front edge of the mantle, above and to the right of the heart, like the renal organ of other Gasteropoda. It subsequently becomes an unpaired hollow sac communicating with the pericardium and the exterior, and the walls consist of a single layer of typical molluscan renal cells. During the larval stage it is thrown to the rear by the alteration of shape which the mantle undergoes. It is further observed that the embryo has the characters of a non-pulmonate rather than a pulmonate Gasteropod, in its early-cast shell, in the form of the foot, and the great development of the velum. The respiratory function of this organ being abandoned, the true organ of respiration has to be discovered; the circulation furnishes the clue to this question. Of the three large longitudinal venous sinuses which receive the blood from the body-cavity, a median one lies along the middle line of the foot, and the other two are lateral and run within the edge of the mantle, near its internal surface. They send out numerous vessels towards its exterior, which break up there into a very elaborate network with narrow meshes, especially developed in the dorsal papillæ. The blood passes from this reticulum into two longitudinal vessels, which lead into the auricle. The surface of the mantle is that part of the body which is best adapted to carry on respiration, by virtue of its rich vascularity and the numerous papillæ which it bears. These papillæ each possess an afferent and an efferent vessel connected by superficial capillaries,

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* Comptes Rendus, xci. (1880) pp. 997–1000.

and may be compared to true branchiæ. It is noticed, in a description of the main arterial system, that the white appearance of the walls of its vessels is due to the presence of particles of carbonate of lime, and not, as has been supposed, to fatty matter.

Digestive, Nervous, and Reproductive Organs of Onchidium.[*]—M. Joyeux-Laffuie discovers, in addition to the radula in the buccal bulb, a chitinous piece, which is of a yellowish-brown colour, is hard and resisting, and is fixed to the anterior end of the base of the bulb; its surface presents a large number of grooves. It is best seen in large individuals. The œsophagus dilates into a proventricular sac; the gizzard has a chitinous internal membrane, is very rough on its surface, and has the small or third lobe of the liver opening into it.

The nervous centres are united into a small sub-œsophageal mass, in addition to which there is a small stomato-gastric ganglion. The former is very difficult to dissect out, but with care it is possible to make out in it the following parts: The cerebroid centre is made up of two ganglia united by a long and large supra-œsophageal commissure; from each of these there pass off commissures to the stomato-gastric, pedal, and pallio-visceral centres. The pedal centre is formed by two large ganglia, and is situated behind the pedal gland; they are united by two commissures, one long and one short, and they give off five nerves to the foot. The pallio-visceral centre is composed of three smaller ganglia, which are united by three short commissures; the outer ones give off all the pallial nerves, while the intermediate one supplies the circulatory system, the genital organs, and a part of the digestive tube.

The shortness of the connecting commissures gives rise to the formation of a well-marked triangular body; from the anterior edge there is the auditory nerve, which passes to the otocyst, placed on the postero-external surface of the pedal ganglion.

Onchidium is monœcious, but the female orifice is placed behind the anus, while the male orifice is found at the side of the right tentacle; the genital organs occupy the posterior portion of the visceral cavity; the so-called uterus is irregular in form; the two albuminiparous glands have their ducts completely distinct, though their constituent lobules are very largely intermixed. The highly "agile" spermatozoa have a dagger-shaped head and a remarkably long tail. The ova, when laid, have a strong shell, and terminate at either end by two prolongations, by means of which the eggs are united together. An account of the development is promised.

Eye of Pecten.[†]—The general absence of organs of vision amongst the Lamellibranchiata meets interesting exceptions in *Pecten* and *Spondylus*, which possess a great number of eyes of considerable complexity situated on the border of the mantle, either at equal distances or clustered together. The number of the eyes also varies in different individuals, ranging in *Pecten* from eighty to one hundred

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[*] Comptes Rendus, xcii. (1881) pp. 144–7.

[†] Quart. Journ. Micr. Sci., xx. (1880) pp. 443–55 (2 pls.).

and twenty. Though it might be supposed that their organization was primitive and simple, their anatomy is found to be exceedingly complicated, exhibiting all the most important structural elements of the eyes of the higher Vertebrata. Mr. S. J. Hickson, believing that these eyes deserve more mention than is usually made of them, describes in some detail the anatomy of the various parts which compose the eyes of *Pecten maximus*, *P. jacobæus*, and *P. opercularis*, illustrated with two plates of eleven figures. Under the head of "General Considerations," the author points out some of the interesting morphological peculiarities of these eyes. It is, in itself, a remarkable thing to find a large and variable number of eyes situated on an area at some considerable distance from any central nerve-ganglion; and, when it is remembered that the class and even family (with one other exception—*Spondylus*) to which the genus belongs, possess no organs of vision at all in the adult condition, it is altogether surprising that they should be of such extraordinary complexity as they have proved to be. The high structural development that this eye has attained is, however, not so remarkable as the fact that in many ways it differs from the ordinary Invertebrate eye, and resembles that of the Vertebrata.

In the first place, the lens is built up of a large number of distinct nucleated cells, which undergo a flattening at its circumference very similar to that found in the eye of the Vertebrata. Whether the lens is developed from the cells of the epiblast, as in the Vertebrata, or from the mesoblast, must at present be left unsettled, but it will probably be found, when the development of the eye is studied, that in this respect also it resembles the eyes of the Vertebrata. The tapetum, a structure which is of considerable importance to animals which are nocturnal or aquatic in habit, has hitherto been described only in the Vertebrata. That *Pecten* possesses a tapetum as highly developed as any found amongst the Vertebrata is anatomically a point of considerable interest, but it also indicates to a certain extent the physiological capability of the eye.

The chief interest, however, lies in the relative positions of the optic nerve, the retina, and the pigment. In the eyes of the Cephalopods the pigment-layer is situated in front of the rods, and the nerve-fibres enter the rods from behind. In the eyes of the Gasteropoda, the Crustacea, &c., down to the simplest form of eye, such as that of the Rotifera, the same relationship of these parts holds good. In the Vertebrata, however, their relative positions are reversed; the optic nerve pierces the retina, and distributes itself over the front of the retina, whilst the pigment is situated behind it. In *Pecten* the relationship of these parts is the same as that in the Vertebrata; the nerve passing up the side of the eye-cup bends over, and spreads itself over the anterior surface of the retina. The pigment also is situated behind the retina. *Pecten* is not, however, the only Invertebrate whose eyes are built up on this type. Semper has recently pointed out that on the backs of certain slugs (*Onchidium*) a number of eyes are found, and that in these the nerves pass to the front of the retina before being distributed. On account of this distribution of the optic nerve, he says that they belong to the Vertebrate type of eye ("typus der Wirbelthieraugen"), so that two animals are now known, each belonging to a large and important class of Invertebrata (Gasteropoda and Lamellibranchiata respectively), that possess eyes which are built up on this type. The eyes of *Pecten* are even more deserving of the name of "Wirbelthieraugen" than those of *Onchidium*, for they are much more highly developed, and possess, in addition to this relationship of the nerve and retina, other Vertebrate peculiarities. The lens is multicellular, a character which, although not unknown amongst the Invertebrates, is much more characteristic of the Vertebrata. The tapetum, too, a structure which doubtfully exists in any other Invertebrata, is found in *Pecten* and some Vertebrates. But, although the application of this word "Wirbelthieraugen" to these eyes is convenient for the adult condition, it must be carefully remembered that the development of these eyes is essentially different from that of the Vertebrate eye. The Vertebrate eye is formed in the embryo from a hollow process, given off from the brain, and the future eye-cup is formed by an invagination of this process. It is impossible for the eyes of *Pecten* or *Onchidium* to be formed by any process similar to this. Thus, in the young state these eyes are essentially different from those of the Vertebrata, and the resemblance in the adult is merely accidental, and by no means due to morphological identity.

Little is known and little can be said concerning the function of the eyes of *Pecten*. The presence of such a well-formed tapetum makes it probable that they are capable of appreciating very diffused light, and the close approximation of the lens to retina makes it exceedingly improbable that any image is formed upon the latter.

A few experiments have been made on the extent of their visual power, which make it very doubtful whether they are of much value to the animal in avoiding its enemies. The most reasonable theory of their function seems to be that when, on the ebbing of the tide, a probability arises that they will be left high and dry on the shore, they can appreciate the fact by the growing intensity of the light, and, by that peculiar flapping motion of their valves the *Pectens* are so remarkable for, move away into deeper water.

With regard to *methods*, the author says that for a general examination of the eye the best method is to harden in alcohol, and stain by immersion in hæmatoxylin for twenty-four hours. Of the osmic-acid preparations the best were obtained by immersion in a 1 per cent. solution for fifteen minutes, followed by absolute alcohol for three or four days. This method is of great value for studying the retina and lens. He also used gold chloride for staining the nerves with some success. For examining the tapetum the best preparations were made from some eyes given him by Mr. Haddon, which had been treated with picric acid. This reagent seems to have dissolved away the red pigment, and consequently left the tapetum free from the numerous little red granules which generally cling to it. For examining the isolated rods of the retina the eyes were allowed to remain in a solution of chloral hydrate for four or five days. The retina was then dissected out with needles as carefully as possible, and a drop or two of hæmatoxylin poured on to the slide. When the retina had been standing in hæmatoxylin in this manner for some hours it was washed with water, teased out with fine needles, and mounted in glycerine.

Molluscoida.

Segmental Organs of the Endoproct Bryozoa.*—M. L. Joliet, after pointing out the causes which so frequently obscure the detection of this organ in *Pedicellina*, describes it as a short stylet, which seems to arise from the point at which the "matrix" abuts on the crown of tentacles, and to pass obliquely downwards towards the œsophagus. Along this stylet it is quite easy to see the ciliary movement, which gives a wheel-like movement to the terminal enlargement; on altering the focus, a similar stylet may be observed on the other side of the œsophagus. When examined with a higher power (No. 9 Hartnack, in place of No. 4), the stylet is seen to be a canal, slightly swollen in its middle, with its axial cavity having the appearance of a blackish line, which is fine at some points and thickened at others; as to the relations of this canal with the exterior, the terminal enlargement is infundibular in form, and its free edge is thickened into a welt, and prolonged into a delicate lip. The internal surface of the canal is covered with vibratile cilia, which work from within outwards, and round the spiral enlargement near the free extremity of the canal.

Characters which speak to the two organs being homologous are to be found in the segmental organ of *Loxosoma;* for the present it seems to be well not to speak definitely of a similar structure in any other Bryozoon. What bearing have the facts adduced on the affinities of these animals? The relations between them and the Brachiopoda, to which Professor Huxley and others have already directed attention, seemed to be aided by the observations now recorded; in illustration of this point M. Joliet gives a useful diagram.

As is well known, the organs which Hancock and Lacaze-Duthiers have shown to be renal organs were formerly regarded as hearts. Translating Professor Huxley, the writer quotes these words: "If we shall succeed in showing that the so-called hearts are not really such, '*ce sera une dissemblance de moins.*'" Speaking for himself, Joliet says: "I hope I have shown that they are the homologues of organs which are also found in the Bryozoa, and at the same point: '*ce sera une ressemblance de plus.*'"

Relationship of the Genus Heteropora to Monticulipora.†—Professor H. Alleyne Nicholson, in an important paper, undertakes a comparative examination of a recent *Heteropora*, with the object of determining if *Monticulipora* should be removed to the Bryozoa. For the purpose he made elaborate examinations of pieces of *Heteropora* in his possession (with specimens of which he had previously furnished Mr. Busk), which were named *H. neozelanica* Busk, but

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* Arch. Zool. Exp. et Gén. viii. (1880) pp. 497–512.

† Ann. and Mag. Nat. Hist., vi. (1880) pp. 329–39, 414–23.

which Professor Nicholson points out Mr. Waters identifies as his *H. pelliculata.*

Professor Nicholson found tangential sections gave the most important results, and these sections showed "numerous delicate radiating spines," which he calls septal spines. In form and arrangement they precisely resemble the septal spines of many species of *Favosites*, and the absence of these in *Monticulipora* is an important point of difference between the two genera. The canaliculi opening into cavities of the tubes by definite pores is a structure that is wanting in *Monticulipora*, and he says that "these canaliculi differ structurally from the 'mural pores' of the Favositidæ."

In *Heteropora neozelanica* he found tabulæ always present, though their number is comparatively small, and these he compares with the partitions or "tabulæ" in *Entalophora* and other Bryozoa; but we may be allowed to point out that these partitions are formed in *Entalophora*, probably on the death of the polypide, in a certain definite position in each species, *one* thus closing the cell, and this is very different to numerous partitions following close upon one another in the same zoœcial tube—as in *Heteropora conifera* Haime, and *H. pustulosa* Haime. From the descriptions and figures it seems possible that there is one partition in each tube, which should then be compared to the partition in *Entalophora* rather than to those in *H. pustulosa*, &c. Professor Nicholson finds the points of likeness between *Heteropora* and *Monticulipora* less weighty than the points of difference, and concludes that there is no real relationship at all between *Heteropora* and *Monticulipora*, so that palæontologists cannot any longer support the Bryozoan affinities of *Monticulipora* by its likeness to *Heteropora;* but he considers that this does not of necessity prove that *Monticulipora* may not belong to the Bryozoa rather than to the Cœlenterata, though his opinion at present leans to the latter. He further points out that it is not without hazard to unhesitatingly assign *Heteropora* a place among the Bryozoa; and while this is certainly true, Professor Nicholson, perhaps, does not sufficiently appreciate that the "septal spines" are very frequent in the Cyclostomatous Bryozoa, although scarcely ever mentioned by systematists, while canaliculi and partitions are also usual.

Arthropoda.

a. Insecta.

Comparative Anatomy of the Nervous System of Insects.[*]—In this note Dr. E. Brandt commences by describing the nervous system of the Coleoptera. Some of these have the sub-œsophageal and thoracic ganglia fused; the cerebral ganglia are always convoluted; there are one, two, or three thoracic ganglia; the number of abdominal ganglia varies greatly, from one to eight; in some (Curculionidæ, Lamellicornes) there are no separate abdominal ganglia; sometimes the number differs with the sex.

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[*] Comptes Rendus, xci. (1880) p. 935.

Of the Lepidoptera the author has examined 118 species (adult) and 42 caterpillars. There are always two cephalic ganglia, and the sub-œsophageal is convoluted. In most there are two distinct thoracic masses; sometimes (as in *Cossus ligniperda*, &c.) there are three. There are always four abdominal ganglia, save in *Hepialus humuli*, which has five.

The Diptera have always two cephalic ganglia, which are separated from one another and connected by short commissures, and here again the sub-œsophageal ganglion is always convoluted; there is frequently only one thoracic ganglion. There are one to eight abdominal ganglia, but these may be altogether fused with the thoracic. *Pulex canis* has eight in one sex and seven in the other, and the same seems to be true of *P. irritans*. The Diptera have a frontal, and two pairs of small pharyngeal ganglia, but the abdominal part of the sympathetic system is not distinct.

Seventy species of Hemiptera have been studied, with the following results:—In some the sub-œsophageal ganglion is fused with those of the thorax; in others, though distinct, it is placed in the thorax and not in the head. The cerebroid lobes are always convoluted. There are three thoracic ganglia in *Pediculus*, but as there are no commissures, they touch one another. The Hemiptera appear never to have any distinct abdominal ganglia, these being in all cases fused with the thoracic portion of the nervous system.

Sensory Nerve-endings in Skin of Insects.*—These have now been found even in places where hairs, bristles, and all other special cuticular formations are absent. H. Villianes has examined the skin of *Musca* and *Eristalis;* he finds the external cuticle to be thick and devoid of the canals which so often occur in it in insects; the hypodermis immediately underlying it is composed of flattened hexagonal cells; a third layer consists of an amorphous connective membrane containing round nuclei at wide intervals. Between this last layer and the hypodermis lie irregular tracts of angular cells, from whose corner proceed filiform processes, which are attached, some to the one, some to the other of the two investing layers, by a triangular flattened disk; the cells are invested by a membrane and contain a round nucleus; the protoplasm does not penetrate into their angles; they become charged with fatty granules towards the end of larval life.

By treating the skin with osmic acid the nervous fibres and cells are demonstrated. The method is to treat the dermo-muscular coat with 1 per cent. osmic acid, and then for ten minutes with 25 per cent. formic acid; it is then left twenty-four hours in $\frac{1}{50}$ per cent. chloride of gold solution in the dark; the tissue is finally exposed to the light in a 25 per cent. solution of formic acid. When the cuticle is removed, a great number of nerve-fibres without Henle's sheath appear between the hypodermis and connective layer; they branch, anastomose, and swell out into a great number of multipolar ganglionic cells, of an average diameter of ·04 mm., and with four or five processes as a rule, of which one, the "centripetal prolongation," is larger

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* Comptes Rendus, xci. (1880) pp. 1089–91.

than the rest and ends in a main nerve-fibre; of the other processes, those which do not end by anastomosis, branch slightly and appear to grow thin and terminate freely beneath or between the hypodermic cells. Frequently the larger nerves beneath the hypodermis exhibit a spherical dilatation, formed by five projections shaped like the segments of a melon and separated by deep grooves; each of these segments contains a fusiform nucleated mass of protoplasm. The author compares the nervous plexus to that observed in Nematodes by Bütschli and Villot.

Relation of Devonian Insects to Later and Existing Types.*—Mr. Scudder is led to think that (1) there is nothing in the structure of these earliest known insects to interfere with the conclusion that the general type of wing-structure has remained unaltered from the earliest times. (2) These insects were Hexapods, and seem to have preceded both Arachnids and Myriapods. (3) They were all allied to or were Neuroptera—using that term in its widest sense, and none exhibit any special orthopterous, hemipterous, or coleopterous characteristics. (4) They nearly all exhibit affinity to the carboniferous Palæodictyoptera; but they often have a more complicated structure than those insects, and have a distinct facies of their own. (5) They were of great size, the span of wing averaging 107 mm.; the wings were purely membranous, and they were probably aquatic in early life. (6) Some, such as *Platephemera*, may be regarded as aberrant forms of existing families; others, such as *Gerephemera*, had a number of parallel veins, such as is found in no other known insect. (7) An abundance of insect life at that epoch is spoken to by their remarkable variety of structure. (8) Not only do the Devonian insects differ remarkably from all other known types, but some of them appear to be even more complicated than their nearest living allies. (9) We cannot therefore say that we are any nearer the beginning of things in the Devonian than in the carboniferous epoch, so far as unity or simplicity of type is concerned. Finally, (10) "While there are some forms which, to some degree, bear out expectations based on the general derivative hypothesis of structural development, there are quite as many which are altogether unexpected, and cannot be explained by that theory, without involving suppositions for which no facts can be at present adduced." The Devonian seem to have but little in common with the Carboniferous insects. The author concludes, however, with expressing his conviction that earlier comprehensive types did exist and should be sought for.

Head and Mouth Organs of Diptera.†—Putting together the observations of the principal writers on these subjects, M. A. Menzbier concludes that:—(1) The insect head consists most probably of six segments, each developed from a pair of embryonic elements. (2) The first segment forms the hinder part of the head and includes the simple eyes. (3) The second segment forms the front part of the

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* Amer. Journ. Sci., xxii. (1881) pp. 111–7; summarized from the Anniversary Memoirs of the Boston Soc. Nat. Hist. 1880.

† Bull. Soc. Imp. Nat. Moscou (1880) pp. 8–70 (2 pls.).

head with the antennæ as appendages. (4) Of the fourth, fifth, and sixth segments, the sixth has a feebly developed main body, which fuses with those of the second and third; this is probably also the case with the fifth, while the fourth is wanting (as in many Diptera) or fuses with other segments. The appendages, however, of these reduced segments are important respectively, as (sixth segment) labium, (fifth) maxillæ, (fourth) mandibles. (5) The third segment is represented by the labrum, and appears to have no appendage belonging to it. (6) The mandibles, maxillæ, and labium are homologous.

In *Musca*, of the three chief external divisions of the head, *epicranium*, *pars basilaris*, *epistomum*, the first is by far the largest. It may be divided into, (1) frons, (2) vertex, (3) occiput, and (4) genæ.

(1) The *frons* reaches from the point of insertion of the antennæ between the compound eyes to the triangular plate of the vertex, which bears the simple eye. Inferiorly the frons has a membranous process, the frontal sac. The *vertex* (2) rises up vertically behind the frons, and extends as far as the fold which surrounds the occipital pit. The *occiput* (3) is divided into two halves by the vertex, and lies behind and to the inner side of the compound eyes. (4) The *genæ* lie in front of the compound eye and in front of and below the frons. The *pars basilaris* extends from the occipital cavity behind to the insertion of the proboscis in front. The *epistomum* forms the anterior wall of the head. It commences at the point of insertion of the antennæ, is bounded laterally by the genæ, and passes directly into the wall of the proboscis below. Behind the head the *neck* is formed by a thin chitinous wall or collar surrounding the occipital cavity. These parts are in many cases but imperfectly distinguished from one another.

The internal skeleton of the head consists of (1) two bands running across the cavity; they connect the pars basilaris and the occiput, and are perhaps fused processes of these parts; of (2, 3, and 4) similar bands between the side of the occiput and the vertex, between the frons and the genæ, and a single semicircular one between frons and epistomum respectively. There are further (5) the septum of the occipital cavity, which consists of two feebly united, hollow lateral processes, between which the brain lies; and (6) the diaphragm of the eyes (*sclerotic* of Leydig), which consists of two rings, an outer one connecting the eye with the head, and one to the inner side of this, surrounding the point where the optic ganglion breaks up into branches. This arrangement of parts occurs in all Diptera, with trifling modifications.

The *antennæ* of *Musca* are situated on the lower edge of the frons and lie in two depressions on the epistomum. At the base of its third segment is a long-fringed, two-jointed process, to which the name *plumula* is applied; some hairs which resemble it, but are not fringed, occur in the second antennal segment. The *proboscis* is studied in connection with the less specialized forms of Dipteran mouths, viz. those of the Tabanid forms, *Hæmatopota* and *Chrysops*. In these insects there is an elongated grooved labrum, and a similar, but more pointed, unpaired organ below and behind the mouth, which is to be regarded as a hypopharynx; a third unpaired appendage proceeds from just behind the latter, in the form of a tube ending in two lobes turned backwards, which is the labium; the mandibles are elongated and knife-shaped, the maxillæ styliform and provided with a pair of palps. In *Syrphus* the structure of these parts is intermediate between that of these species and that of *Musca*. The labrum is a veritable proboscis, and has, as in *Musca*, a basal, median, and terminal division: the basal is thin and shaped like a truncated cone; the median is thin and cylindrical, chitinized only in the front and hind walls; the terminal division consists of the lobes which contain pseudotracheæ. Within the basal part is a kind of chitinous tube having very much the position of the labium in *Hæmatopota* and *Chrysops*, being a continuation of part of the œsophageal wall; it is probably homologous with the labium. The labrum is united with the epipharynx at the base of the labium. The hypopharynx, mandibles, and maxillary palps agree with those of the other two genera, but the maxillæ are extremely rudimentary. *Empis livida* makes a nearer approach to *Musca*. The labrum is still more closely united with the epipharynx; the maxillæ appear to be rudimentary but to have palps; the mandibles are absent. In *Musca* the mouth organs consist only of labrum, epipharynx, labium, and maxillary palps. The labrum and labium are developed from paired rudiments, but the former appears to represent the body of a segment, while the latter truly belongs to the series of appendages. *Sargus* represents a still higher degree of reduction, for the mouth parts consist only of labrum, labium, and what are probably maxillary palps.

Thus the mouth parts of Diptera can be referred to their homologues in the typical insect mouth; they may be either fully developed or much simplified: an epi- and a hypo-pharynx are often present, as processes of the œsophageal wall; the former usually fuses with the labrum. The modifications in the development of the mouth parts bear a certain relation to the nature of the food and the manner of obtaining it.

Scent-apparatus of Sphinx ligustri.*—With reference to the experiments of Von Reichenau † on this subject, K. Fügner mentions finding that no trace of the characteristic musky odour was emitted by a living male specimen of this insect so long as the animal remained quiet; but the frequent motion up and down of the folds of skin lying at the base of the abdomen on both sides indicated the position of the organs in question. The scent and tufts of scent hairs become apparent when the wings are gently pressed upwards. When the insect is excited to vibration of the wings by the presence of some vapour of spirit of wine, the skin-folds open out, exhibiting the tufts of hair and assuming the form of raised cups made up of stout brownish scales; the white scent-hairs form a strong contrast to the darker scales. The hairs perform a peculiar undulating movement, the cause of which was not determined, and the scent becomes at once

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* Entomol. Nachrichten, vi. (1880) pp. 166–7.

† See this Journal, iii. (1880) p. 938.

evident. E. Lelièvre [*] has observed a scent in imagos of *both* sexes of *Thais polyxena* which had freshly emerged from the pupæ; the liquid which adhered to the fingers when the insects were touched had rather the odour of the *Aristolochiæ*, the plants on which the larva feeds, than that of musk. *Spilosoma fuliginosa* also has a scent which resembles that of the *Zygœnæ*.

"Houses" of the Larvæ of the Trichoptera.[†]—We have here a translation into German from the Portuguese of Dr. Fritz Müller, who commences by pointing out that the order of the Trichoptera is doubly interesting, from a genealogical, as well as from a biological, point of view. They have much the same relation to the Lepidoptera as the anthromorphous apes have to man; it is in the highest degree probable that the Lepidoptera were derived from some extinct Trichopteron, or, at any rate, that the two orders arose from a common stem-form, from which the inconspicuous Trichoptera have slightly, and the highly coloured Lepidoptera have greatly, diverged.

Nothing appears to be known as to the natural history of any extra-European forms; with the habitations of the separate families we must deal very briefly.

(1) The Rhyacophilidæ have their covering always so arranged as to allow of the passage through it of a stream of fresh water, which is necessary for the respiration of the contained larvæ.

(2) The Hydropsychidæ form tubular houses of some kind; the larva lives in a kind of canal or passage, covered by loosely attached stones; when the larva is about to pass into the pupa-stage the stones that form the house are more firmly built together.

(3) The Leptoceridæ all have movable "houses," which are nearly always in the form of narrow, conical, somewhat curved tubes. The larvæ differ much in the material which they use, and in the way in which they fix its parts and close it, when they are about to become pupæ.

(4) The Sericostomidæ have, as is well known, heliciform cases.

(5) The Hydroptilidæ present some variations among themselves; in addition to the two forms classified by Willoughby (1710) as (*a*) "immobili seu lapidibus affixa," or (*b*) "mobili aut portatili, migratoria," there is here a third, "theca lapidibus affixa, mobili."

The coverings of certain species of indefinite systematic position, are also described, and in an appendix the author enters into a consideration of the systematic characters of the different groups, in which he takes for his basis the classification of Mr. Maclachlan. The paper being essentially one of elaborate details, we must refer to it for fuller information; it is illustrated by thirty-nine figures in two plates.

γ. Arachnida.

Blastoderm of the Araneina.[‡]—M. Sabatier states that shortly after oviposition the ovum of these Arachnida is covered by a

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[*] Cf. also 'Le Naturaliste,' June 1st, 1880.

[†] Zeitschr. wiss. Zool., xxxv. (1880) pp. 47–88 (2 pls.).

[‡] Comptes Rendus, xcii. (1881) pp. 200–2.

continuous layer of protoplasm, the presence of which was wrongly denied by Ludwig; this layer becomes distinctly marked off into germinal areæ; this division is due to the protoplasm being taken into the interior from the surface of the egg. Hyaline protoplasm becomes intercalated between the yolk-spheres of the surface. This phenomenon has no special influence on the formation of the blastoderm; it is rather the result of a centrifugal action of the protoplasm.

After criticizing some of the observations of Ludwig, the author says that, in the Araneina, the protoplasm passes from the centre to the periphery, where it appears under the form of discs or "cones d'éjection," surrounded by a wreath of spheres. This process divides the ovum into a meroblastic egg, with a number of cicatriculæ. In the second period of its history the egg gives rise to a second generation of similar cells. The superficial protoplasm continues to segment, and finally forms a simple layer of flattened polygonal cells. The observations of the author combat in many points the results of Ludwig.

δ. Crustacea.

Crustacea from the Gulf of Mexico and the Caribbean Sea.*—In his preliminary communication, M. A. Milne-Edwards describes a large number of new genera and species.

Trachymaia (near *Halimus* and *Amathia*) is represented by *T. cornuta*. *Lispognathus* is intermediate between *Euprognatha* and *Anisonotus*: *L. furcatus*. *Anasimus* (*A. fugax*) is allied to *Podochela* and *Anisonotus*.

Among the Carcinoplacida, we have *Frevillea* with *F. barbata*, *F. rosea*, *F. Sigsbei*, and *F. tridentata*. The blind *Bathyplax* is allied to *Carcinoplax*: *B. typhlus*. *Eucratoplax* is intermediate between the *Panopæidæ* and *Euryplax*: *E. guttata* and *E. elata*.

Trichopeltarion (*T. nobile*) is a new genus of the Oxystomata.

In the *Dorippidæ*, we have *Corycodus*, with a globular carapace: *C. bullatus*. *Cyclodorippe* (*C. nitida*, *C. antennaria*, and *C. Agassizii*) is like *Cymonomus* (*C. quadratus*) and *Cymopolus* (*C. asper*) intermediate between the Dorippidæ and the abnormal Brachyura.

In the *Dromiadæ* there appears *Acanthodromia* (*A. erinacea*), which is intermediate between *Dromia* and *Dynomene*; and *Dicranodromia* (*D. ovata*), *Homolodromia* (*H. paradoxa*), and *Homolopsis* (*H. rostrata*).

Raninops (*R. constrictus*, *R. Stimpsoni*) is a new Raninid.

In the *Pagurida*, we have *Xylopagurus* (*X. rectus*); *Pylocheles* (*P. Agassizii*) is near *Pomatocheles*; *Mixtopagurus* (*M. paradoxus*) allies *Pagurus* with *Pylocheles*. *Ostraconotus* (*O. spatulipes*) has the carapace entirely coriaceous. *Catapagurus* is intermediate between *Ostraconotus* and *Spiropagurus* (*C. Sharreri*).

In the *Macrura*, we have *Galacantha* (*G. rostrata*, *G. spinosa*); *Galathodes* (*G. erinaceus*, *G. spinifer*, *G. robustus*, *G. serratifrons*, *G. abbreviatus*, *G. Reynoldsi*, *G. simplex*, *G. Sigsbei*, *G. latifrons*,

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* Bull. Mus. Comp. Zool. Camb., viii. (1880) pp. 1–68 (2 pls.).

and *G. tridens*); *Orophorhynchus* has as new species *aries*, *spinosus*, *Sharreri*, *nitidus*, and *spinoculatus*; *Elasmonotus*, *E. longimanus* and *E. brevimanus*, *E. armatus* and *E. abdominalis*. The new genus *Diptychus* has the general form of a *Galathœa*: *D. nitidus*, *D. uncifer*, *D. armatus*, *D. rugosus*, and *D. intermedius*. *Ptychogaster* (*P. spinifer*).

Among the Scyllarids the only new genus is *Palinustus* (*P. truncatus*). Want of space altogether prevents our giving the names of the numerous new species which belong to generic forms already described; and, indeed, space must still be kept, for we have not yet in hand the whole of even the preliminary account of this really marvellous collection of Crustacea.

Sensory Rods of First Pair of Antennæ in Crustacea.*—In the Podophthalmia, S. Jourdain finds that these consist of slender cylindrical hairs, each covered by a delicate chitinous layer, and divided into a variable number of joints; the free end has the form of a truncate cone, and bears a hyaline process, which probably has a sensory function; within the sheath is a granular substance, derived, apparently, from the dermal layer or chorion; a nervous fibril has been traced to the base of the hair. These rods are variously distributed in the different groups, but they agree in the fact that when the antenna is branched they occur on one only of the branches. In the *Brachyura*, this principal branch is short, and on one side of it are arranged the rods in transverse rows, which diminish in breadth towards the apex of the antennæ, which is bare of them, as are also the first three or four joints at the base; the branch has thus the form of a brush, and the different rows of rods move to or from each other with the movements of the antennal joints; in life it is always in motion, dashing abruptly through the water; alimentary particles entangled in it are removed by the palps of the second pair of maxillipedes. The antenna is very sensitive to external impressions.

In the *Anomoura* the essential characters of the antennal brush are those which prevail in the *Macrura*. In the latter the antenna is not retractile into a cavity, and its movements, though abrupt, are far less frequent than in the *Brachyura*; the principal branch bears the sensory rods, generally in double rows, on the basal joints alone; the number of rods in each row is small.

In the *Oligognatha* (*Hedriophthalmia*) the structure of the rods is essentially the same as in the foregoing groups, but their arrangement shows an immense number of variations; as a rule, the antenna in question (*antennule*) has no special movements, and the number of rods is not great. The function of the rods must be admitted to be sensory, but there is nothing in their structure to prove them to be specially devoted to the sense of *smell*.

Australian and Tasmanian Amphipods.†—Mr. W. A. Haswell records 12 new species of Amphipods, with a new genus *Aspidophoreia*.

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* Comptes Rendus, xci. (1880) pp. 1091–3.

† Proc. Linn. Soc. N. S. Wales, v. (1880) pp. 97–105 (3 pls.).

This differs from *Stenothoë* Dana in having the ramus of the last pair of pleopods uniarticulate; in most of its characters it approaches *Allorchestes*, being distinguished from it only by the largely developed anterior coxæ and the character of the telson.

Circulatory Organs of Isopoda.*—M. Delaze states that the heart of these Crustacea is situated in the abdomen, and extends more or less into the thorax. It is altogether dorsal in position, tubular when long, pyriform when short. It communicates with the pericardium by two or four orifices, which close when the heart contracts. When the heart does contract, it not only diminishes in volume, but produces a kind of vacuum, and so a kind of aspiration, which attracts fresh quantities of blood to the pericardium. Eleven arteries—one thoracic, two abdominal, six thoracic, and two lateral—are given off from the heart. These arteries have bilabiate valves at their orifices. After describing the course taken by these vessels to the various organs which they supply, the author points out that there is developed a peri-œsophageal vascular collar, placed above the œsophageal commissures. From this collar there is given off a pre-neural artery, which passes to the anus along the anterior median line of the body, above the ganglionic nervous chain. The ventral arterial system is formed by seven pairs of branches derived from the thoracic arteries, and by others given off from the pre-neural artery. These unite by anastomoses, and in some cases give rise to a superficial vascular circle. There are no capillaries, the arterioles passing the blood into interstitial lacunæ, the largest of which is found in the thorax.

At the base of the thorax the two chief thoracic sinuses unite, and give rise to a large abdominal sinus, which is situated in front of the rectum. From this sinus five pairs of vessels pass off to the gills.

It ordinarily happens that certain parts of the abdomen, such as the telson, or the epimera of the branchiferous somites, are adapted for the purposes of respiration. Five pairs of branchio-pericardiac vessels, formed by the efferent branchial canal, pass backwards, and open into the pericardium by non-valvate orifices.

The pericardium surrounds the whole of the heart, except in front, where it is united to the rectum. It is generally formed by a distinct membrane, and its walls appear to be invested by a layer of endothelium. With the exception of the first-mentioned orifices, it is closed, except on its superior surface, where there are some small lacunæ. A small number of globules which have not undergone the respiratory process enter by these clefts, and mix with the blood which has come from the branchiæ. Some of these have returned from the thoracic lacuna by means of the dorsal arcs, which are placed just below the integument.

New Type of Parasitic Crustacean.†—M. Lacaze-Duthiers describes a new parasitic Cirriped (*Laura*), which he has found living on that Antipatharian form to which he has already given the generic name of *Gerardia*. Seen from without, it is reniform in shape and its

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* Comptes Rendus, xcii. (1881) pp. 63–6.

† Arch. Zool. Expér. et Gén., viii. (1880) pp. 537–81.

body is imbedded in the cœnosarc of a *Gerardia;* the "carapace" is formed of two scales or valves united along the middle line. On the side opposite to the adherent edge there is an orifice, which is probably only the remains of the separate condition of the two valves, which obtained during its *Cypris* stage. The "hilum" of the kidney-shaped body corresponds to the anterior or abdominal face; the head of the animal is close to the deepest point of the hilum, and the tail corresponds to the opening of the carapace. Originally, no doubt, the carapace was attached by the dorsal portion intermediate between the head and the abdomen. The body is little more than one centimetre long, and the carapace is two, three, or four times as long as it.

This carapace is hard and cartilaginous externally, and is limited internally by a soft layer; between these there is lodged the liver and one of the genital glands, together with a very rich vascular plexus. The external covering is riddled by a large number of small ducts, the outer orifices of which are covered by a membrane, which is surrounded by delicate filaments; these are of cartilaginous consistency, and have a central duct. They appear to be formed of the general connective tissue: the canaliculi given off from the duct pass into the base of the filaments.

A study of the circulatory organs shows that the tissues on the inner face of the carapace are supplied with a rich capillary plexus, which surrounds all the organs, and gives rise to nutrient lacunæ. These communicate with the internal orifices of the canals, so that we may say that *Laura* gives off thousands of radicles, which force their way into the tissues of the *Gerardia.* The peculiar arrangements of the digestive system confirm this view.

Passing over other points in the carapace, we come to the body of the animal. This consists of eleven rings, or twelve if we count the two caudal valves as a ring. The first two are smaller than the succeeding four; the whole body is S-shaped in form, but the superior curvature is stronger and larger than the inferior. The eleventh ring ends in four large unequal cirri. There are six pairs of limbs, of which the first five have more function as accessory reproductive than as locomotor appendages. The first five appear to be on the first five segments; the sixth are near the anal extremity.

The digestive system is described in detail. We have here only space to say that the liver is of great size, that buccal and anal orifices appear to be absent, and that the digestive tube is always full of a yellow, pultaceous matter, which appears to be similar to the hepatic secretion. After describing the circulatory arrangements, the author points out that direct alimentation probably does not obtain in this creature; absorption is effected by the carapace; the absorbed products are purified by the biliary secretion, which here at any rate appears to have a depuratory function.

There are four pairs of testicles, which are placed at the base of four pairs of legs. The ovary is found in the carapace, and the ducts open on the first pair of legs. The animals are truly hermaphrodite, and fecundation appears to be accomplished within the carapace. The young have a *Nauplius*-stage.

In the present unsatisfactory condition of the classification of the Cirripedia, M. Lacaze-Duthiers temporarily propounds the following scheme:—

Cirripedia abortiva
1. Suctoria aut Rhizocephala (*Sacculina*, *Peltogaster*).
2. Apoda (*Proteolepas*).
3. Abdominalia (*Crytophyalus*).
4. Ascothoracida *sive* Rhizothoracida (*Laura*).

The last sub-order is incontestably higher than the three other groups.

Vermes.

Seison.*—Professor C. Claus having lately continued his investigations into the anatomy of this obscure parasitic Rotifer, describes in some detail the organs originally assigned by him to the water-vascular system. The two "transparent canals" of his former account are the ascending portions of an extensive system of tubes: they exhibit, close to their attachment to the integument, a pair of strongly ciliated lobes which project into the tubes, but cannot be considered as ciliated excretory funnels.

In the female the thin transparent main canals already mentioned, commencing at the upper part of the central division of the body, each send a long loop forwards into the neck and themselves pass backwards and downwards through the body to the gland of the "foot"; here their walls assume a glandular character. The anterior end of the canal having passed the turn which formed the loop, now passes in the same way backwards, and after being twice alternately dilated and constricted, passes up towards the anus and expands into a delicate sac which probably opens with the rectum to the exterior. Into the same sac opens the other (glandular) tube. In the male, the posterior division of the canal is much more slender than in the female, and the glandular character of its wall is wanting. After winding in a complicated manner, it passes up towards the dorsal surface at a considerable distance from the abdominal ("foot-") gland and then becomes in some way connected with the excretory part of the male organs. A similarly striking difference between the characters of the two sexes is presented by the digestive organs: thus in the female the rectum is sheathed with longitudinal muscles, and ends in a dorsally placed anal slit; in the male, however, it is altogether wanting from this place, for it opens on the neck with the ductus ejaculatorius; in the male, too, the muscles which move the chyle intestine have quite different insertions and positions from those of the female.

The peculiar bean-shaped organ which receives the vasa deferentia of the male is probably derived from the unpaired portion of the water-vascular system. On the right of the orifice of the male duct a lobate diverticulum opens, and on its left a multifid glandular mass. A fuller and illustrated account is to appear, and will no doubt throw light on some of these obscure points.

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* Zool. Anzeig., iii. (1880) pp. 548–50.

Organization of Echiurus Pallasii.[*]—Dr. Spengel continues his valuable essays on the characters of the Gephyrea by an account of his observations on this form.

Commencing with an account of the dermo-muscular tube, the author points out that the dermis consists of an epidermis, a covering cuticle, and an internal cutis. These parts are different on the trunk and on the cephalic lobes. Unicellular glands, pyriform in shape and with a more or less long neck, are arranged with a good deal of regularity on the trunk; they are arranged in groups, which form papilliform elevations. These papillæ are set in transverse series around the body, and rings of larger papillæ may be found to alternate with three or five rings of smaller ones. The structure of these parts seems to be very difficult to make out, but in the centre of each a pore may be distinctly seen, and round about it there are a number of bright spots. The pore leads into a short canal, which is bounded by a number of cells, some of which are undoubtedly glandular in character; others would seem to have a sensory function; well-developed nerve-branches pass into the papillæ. The cutis of the trunk forms a connected layer of varying thickness, consisting of a gelatinous homogeneous ground-substance, in which stellate cells, connected one with another, may be made out, together with "balls" of cells, which are filled with reddish-brown or yellowish pigment-granules. In the cephalic lobes there is a difference between the characters of the dorsal and of the ventral portions of the dermis, for the latter has a ciliated cylindrical epithelium, placed in lines along its lateral and anterior margin.

The muscular tube consists of three layers; the outermost is formed of circularly set fibres, then follows a layer, three or four times as thick, of longitudinal fibres, and the third, which is again thinner, has an oblique direction; and the whole system is bilaterally symmetrical on either side of the middle line of the body. This excessive development of the contractile layer explains the wondrous variations in form of which its possessor is capable. Towards the posterior end the circular muscles are alone well developed, and there they appear to take on the function of a sphincter. On the other hand, although there are some changes in the disposition of the parts, the musculature is excessively well developed in the region of the cephalic lobes; and in addition a number of delicate dorso-ventral muscles are developed.

Two kinds of setæ are found in *Echiurus*. The first set consists only of two (the "unguiculi genitales" of Pallas); in either of them there is a cylindrical shaft, about 6·5 mm. long in the adult, and a curved hook of 2·5 mm. The latter is of a golden yellow, and the former of a whitish colour. The hook would appear to be structureless, but the shaft gives indications of being made up of a number of fine fibres. Each seta is surrounded by two sheaths; the inner one is chiefly formed by an epithelium directly continuous with the epidermis; it is, in fine, the setal follicle. The component cells shed out a cuticle; the outer sheath is similarly bilaminate, its homo-

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[*] Zeitschr. wiss. Zool., xxxiv. (1880) pp. 460–538 (4 pls. and 2 figs.).

geneous ground-substance being covered by a very thin investment. The muscles which move the ventral setæ are inserted into this outer sheath, and these muscles are to be distinguished by their relation and characters. In addition to these ventral setæ, which are formed in all the Echiuridæ, there are others which are peculiar to the genus *Echiurus*. They form a group of from thirteen to sixteen, which are arranged in two rows around the anus, and may consequently be known as the anal setæ. They each consist of a straight shaft which, like that of the ventral setæ, lies in the body, and of a straight or slightly curved projecting hook. These would appear to have, as the ventral setæ certainly have, a locomotor function; but it is as yet impossible to define more exactly the rôle that they play. After a description of the reserve set of setæ the author passes to the

Nervous System.—The central portion is formed on the type of *Bonellia*, as described by Lacaze-Duthiers. Along the middle ventral line of the cœlom there runs a ventral medulla, which divides anteriorly into two processes which are connected by a dorsal supra-œsophageal arch. The ventral portion is, in the adult, an almost cylindrical cord, made up of cellular and fibrous elements; the former chiefly occupy the sides and part of the dorsal region, while the latter form the internal and the ventral portion. In cross section the ganglionic masses exhibit, therefore, a well-marked bilateral symmetry, and are more closely approximated to one another in the dorsal than in the ventral parts. The relations of the cells to the fibres are very difficult to detect, and of the fibres many are certainly of other than a fibrous nature. The true nerve-fibres would seem to be arranged in regular bundles. It is of great interest and importance to note that in the young the arrangement of the ganglionic cells is less regular. They do not form an uninterrupted and regular band on either side, but are found in greater quantities at certain points, and are for short spaces almost completely absent. Thus, then, they call to mind the arrangements which obtain in the Annelides. The reality of the bilateral symmetry is best spoken to by the relations of the peripheral nerves; those of either side always exactly correspond. The remarkable arrangement detected by Keferstein and Ehlers in *Sipunculus* has also been observed in *Echiurus*. Each nerve runs for a short space through the cœlom, and then passes almost perpendicularly through the inner and median muscular layers, whence it runs parallel to and between the circular muscles and the longitudinal layer towards the back, where it unites to form a circular ring with its fellow of the opposite side. A somewhat problematical structure is to be seen in transverse sections of the ventral cord. This is the so-called longitudinal canal, which lies just below the dorsal middle line, and which in preparations is often filled with a coagulum. It is easy to compare it with the similarly problematical structures found in Annelids and known as the giant nerve-fibres of Leydig, the tubular fibres of Claparède, or the neural canal of M'Intosh. The latter name is adopted by Dr. Spengel for the cavity found in *Echiurus*. Anteriorly it passes into the œsophageal commissures. Some attempts have been made to compare this structure with the central canal of the Vertebrate spinal cord, but the observations of Hatschek which would support this view are not in agreement with the description of the development of the ventral medulla of *Lumbricus*, as given either by Kowalevsky or Kleinenberg. Nor do Dr. Spengel's own observations on the development of *Echiurus*, or the fact that the canal is continued into the œsophageal commissures, support the doctrine of Dr. Hatschek. Only one ganglionic band passes into each of the commissures just mentioned, and in them some of the ganglionic cells lie on the ventral side. Of the anterior peripheral nerves some would appear to be justly called *tactile*.

The enteric canal is a good deal complicated. Its two orifices are at either end of the body; the mouth, which can be closed by a sphincter muscle, leads into a wide pharynx, and at its hinder end there is a diaphragm. This structure calls to mind the dissepiments of the Annelids, and would appear to be of very considerable significance as an indication of a division of the body into two segments. The œsophagus which follows the pharynx is succeeded by a very short but wider portion—the crop. The rest of the coiled enteron is several feet long, and appears to be divisible into three portions. In the mid-gut there may be seen on the ventral side a ciliated groove bounded by two epithelial ridges, and a band of longitudinal muscle. Behind the mid-gut the tract is divided into two canals, very different in their diameter, but closely applied to one another along their whole length. The narrow one is never more than 1 mm. in diameter, the other varies considerably. The former would be comparable to the secondary gut of the Echinida (Ludwig) and of the Capitellida (Eisig). Where the "hind-gut" joins the rectum, we find the openings of the so-called "anal tubes." To these structures the author passes after an account of the histology of the different regions of the enteron. They are two in number, reddish-brown in colour and varying in size. In young individuals it is possible that their size is continually changing, owing to the great contractility of their walls. This last peculiarity is, also, a very sufficient cause for great misapprehensions as to their true structural characters, and it is always best to study tubes which are found filled with fluid. When carefully examined, each tube is seen to form a greatly elongated non-ramified sac, the walls of which contain three or four layers. The outermost is the peritoneal investment, and it is followed by a muscular stratum divisible into two layers. The constituent fibres cross one another in various directions and form an irregular network; in sections it is possible to see that two distinct directions are taken by these fibres, for some are circularly and some longitudinally disposed; the former are the more external. The contained epithelial layer has a complicated structure. Broad spindle-shaped groups of cells are to be found between the flattened cells, and the former have extremely delicate, very long cilia. These groups of cells are arranged in pretty regular longitudinal lines, and, owing to their pigment, are the cause of the brown coloration of the organ. The surface of each tube is beset with a very large number of small clear corpuscles, in which we may detect infundibular bodies provided with exceedingly long and active cilia. Each of these funnels forms a part of a "ciliated organ," part of which is also made up by a short and narrow canal, which lies in the wall of the anal tube, to the long axis of which it runs parallel, and into which it finally opens. The canal is lined by a ciliated epithelium. Of the numerous infundibula on the surface one deserves especial mention; it is the one which lies at the tip, is larger, and is, no doubt, morphologically the primary infundibulum. When we come to consider the exact character of these tubes, which have been by all observers regarded as appendages of the enteron, we are met by the difficulty of having to define what is the true end of that tract; they open behind the sphincter-like thickening of the circular musculature of the hind-gut, and between it and that anal portion which is so well provided with glands. This last would seem to be a portion of the outer skin, and if it be so it is probable that the "anal tubes" have morphologically no relation to the true enteron; but this is a point which can only be decided by further investigations, and especially by those undertaken from the embryological side.

It will be seen that these results are very far from being in accordance with those of Greef; * and Dr. Spengel proceeds to point out what he believes to be the misleading influences in Greef's experiments.

The vascular system is very simple, consisting merely of a ventral and of a dorsal vessel, with two connecting loops. The contained fluid is colourless and the corpuscles are amœbiform, with long sharp pseudopodia, or are stellate. Similar cells are found in the cœlom, but no connection between the two systems of cavities could be made out.

The spoon-shaped cephalic lobe is shown to contain a number of hollow spaces, the whole system of which is a continuation forwards of the cœlom. After this we come to the segmental organs, of which there are two pairs. The anterior lies behind the anal setæ, and the posterior some way further back. In front of their orifice they give off a short, and behind it a longer sac; in their walls we find an internal epithelium, two layers of muscles, and a peritoneal investment. In some cases balls of pigmented cells are to be detected below the epithelium, and it is these aggregations which give rise to the apparent presence of a vascular plexus. These balls would hardly seem to be products of excretion. The cavity of each segmental organ communicates freely with the cœlom; the infundibula are provided with membranous valves; by the segmental organs, the product of the last set of organs to be described, escape to the exterior. These are the generative organs, the characters of which are very indifferent, so that it is safer to call them germ glands than to distinguish them as testis or ovary. The gland lies at the hinder end of the body, and gives rise to spheres of cells. In the female there are not, as in *Bonellia*, any investing cells around the primitive ova. When the groups of cells break off from the gland they move freely about in the cœlom; in the male the cells are set free in groups of from thirty to forty, and, unlike the ova, they long remain connected together. The author, in a supplementary note to this long paper,

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* See this Journal, iii. (1880) p. 434.

discusses some of the statements made by Greef in his larger paper on the Echiurida (in the 41st vol. of the Nova Acta Leop.-Car. Akad.) which only came into his hands after his own paper was concluded.

Nematode Worms in the Urine.*—A case of the occurrence of one of these worms in the urine of a woman is recorded by Dr. S. H. Scheiber, from Hungary; the chief accompanying symptoms were a slight bronchial affection, abdominal pains, loss of appetite, moderate febrility; the urine was scanty and dark, and contained albumen, pus- and other cells, and a great number of living and dead worms, a low proportion of urates and chlorides, &c. The larger worms were provided with distinct generative organs, and lived for three days in alkaline urine. Many thousands of these worms must have been passed in the day; their origin was ultimately determined to be the generative organs of the patient. They agree in structure with the genus *Rhabditis* of Dujardin, the members of which genus are usually free-livers, inhabiting stagnant water or foul damp soil, but are sometimes entoparasitic; this species is provisionally named *Rh. genitalis.*

Studies on the Cestoda.†—M. Moniez, in dealing with the ovary of *Tænia serrata*, points out that, in addition to the two ordinarily recognized ovarian glands, the so-called albuminiparous gland is a third organ of the same set; this last is attached to the tube by which the ova pass into the uterus; it varies in form in different species.

The histology of the uterus has been studied in *T. crassicollis;* in it the cellular investment of the uterus may be seen to disappear suddenly.

In many species the sperm-duct has no primary communication with the testicular follicles and ends in a cul-de-sac. In *Leuckartia* this is very well seen; on the other hand, in young specimens of *T. crassicollis* branches communicating with the male glands have been observed.

Dealing with the calcareous corpuscles, the author gives an account of his studies on *Ligula;* there he finds them arising at the expense of the fusiform cells of the general tissue, which increase in size without altering in form, and take on a vitreous appearance under the influence of reagents. This does not last long; soon there is formed, at the expense of the greater part of the contents, a more or less spheroidal body which is distinguished by its denser aspect; this is the future calcareous body; the writer compares the process with the formation of calcareous bodies in certain Turbellaria, as already described by Hallez.

The ovary is well developed in *Ligula*, where it is unilateral and ventral. A prolongation of this ovary into the central parenchyma recalls the characters of the ovary of *Leuckartia*; but here it remains rudimentary. The ovarian tube is sometimes very short when the eggs pass into the parenchyma.

The penial pouch of *Ligula* has added on to it a bulbous enlargement

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* Arch. Path. Anat. Physiol. (Virchow), lxxxii. (1880) p. 161, and part of pl. v. (figs. 1–7).

† Bull. Sci. Dép. Nord, iii. (1880) pp. 356–8, 407–9.

similar to that of *Bothriocephalus* and *Schistocephalus*; in *Leuckartia*, where the sperm-duct is well developed, the cells of its walls give rise to a plexus which allows of the direct entry of the spermatozooids.

New Cestoid Worm.*—The remarkable *Urocystis prolifer*, which is found parasitic in *Glomeris limbatus*, is to be noted for the fact that it passes through the different stages of its life within the same host. When in its vesicular condition it lives in the body-cavity, and in the scolex stage it is encysted within the fat-body. In the former state it consists of a head, a body, and a caudal vesicle. The oval head is provided with four suckers, and a very long rostellum; this last is invaginated into the head at its posterior extremity, and into itself at its anterior, giving rise almost to the appearance of a frontal sucker. The inner wall of this infundibulum presents a number of transverse folds, and is armed by a crown of excessively small hooks. The body consists of a very delicate membrane, and below the neck there is a kind of pad formed of embryonic cells; the caudal vesicle is oval, and is excessively contractile. The whole parasite does not exceed an Infusorian in size. The following is its mode of multiplication: the joints are developed successively, and break off when they become mature. Ordinarily we find a vesicle entirely developed into a head, associated with a bud which has the form of a caudal appendage; at the moment when the first signs of the scolex appear, the two individuals are very slightly connected together. When it becomes detached the vesicular bud is found to contain a perfect scolex. This last rapidly frees itself of its caudal vesicle, and makes its way into the fat-body of its host.

Here the scolex does not undergo any great modifications; it takes on a spherical form, and the embryonic cells in the wall of the "body" are converted into elastic fibres. With certain relations to *Staphylocystis*, it is at any rate distinguished from it by not forming colonies. The definite host, whether bird or mammal, belongs, as M. Villot thinks, to the Alpine fauna; the *Glomeris* from which he obtained his specimens was captured in the woods of La Grande Chartreuse.

Loss of Hooks and of the Scolex in the Tæniadæ.†—M. Mégnin not only brings forward further evidence in support of his proposition ‡ that the armed and the unarmed states of a Tænia are constant and successive in the same species, but that there is, further, an equally constant *acephalous* condition; in other words, the scolex, just like the hydatid vesicle, is a transitory structure. "It is only one more of the many means of multiplication of which Nature has, among the Cestoda, shown herself so munificent."

In certain species the detachment of the first rings is an expression of the cessation of the functions of the scolex, which now ceases to bud and to produce; its duty is at an end. It is now gradually absorbed, first losing its hooks and then its suckers, till finally it disappears altogether. As examples of these processes, the author

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* Comptes Rendus, xci. (1880) p. 938.

† Journn. Anat. et Physiol. (Robin) xvii. (1881) pp. 27–45 (2 pls.).

‡ See this Journal, iii. (1880) p. 444.

puts forward an account of the life-history of *Tænia lanceolata*, and gives figures in illustration. The other two species selected are *T. infundibuliformis*, and the other the new species, *T. echinobothrida*, both of which belong to a group of the Tænias which the author proposes to call *Echinobothridia*. These forms have the suckers, as well as the rostrum, provided with hooks. The first-named species has been found in abundance by the author in the intestines of pheasants attacked by *Syngamus trachealis*. It seems that the first to disappear are the hooks of the suckers, then the suckers themselves, then the hooks of the proboscis, and finally the scolex gradually becomes absorbed.

The writer then gives a diagnosis of the new species, *T. echinobothrida*, which he found in some fowls, and an account of the different phases through which it passes.

In conclusion, attention is directed to the very natural question, Do other armed Tæniæ, and especially those found in man, follow the same rules as to the progressive loss of the hooks and the final absorption of the scolex? Analogy would lead us to think so, and there are observations on *T. solium* which support the proposition. Leuckart, who has noticed it, attributed it to old age, and the author gives a figure of one, in which we note that the proboscis is merely represented by a slight eminence, without any hooks, and in which the suckers have disappeared. In an example studied by Küchenmeister the hooks disappeared when the Tænia was not 8 mm. long.

Echinodermata.

New Echinoidea.*—Professor Alexander Agassiz has published a list of the specimens collected on board the U.S. Coast Survey steamer 'Blake' in the Caribbean Sea, 1878–79, and along the Atlantic coast of the United States in 1880, together with short descriptions of twelve new species: *Dorocidaris Bartletti*, *Porocidaris Sharreri*, *Podocidaris scutata*, *Aspidodiama microtuberculatum*, *A. Jacobyi*, *Asthenosoma Reynoldsi*, *Phormosoma Sigsbei*, *P. Petersi*, *Echinus Wallisi*, *Palæotropus Thomsoni*, *Palæopneustes hystrix*, *Hemiaster Mentzi*, and *Schizaster Orbignyanus*. It will be seen that many of these new forms belong to some of the most interesting genera in the group; in many cases examples of species already described larger than any yet obtained were taken by the dredge.

Perivisceral Fluid of the Echinoidea.†—Mr. P. Geddes remarks that the close resemblance between the uncoloured elements of the blood, the amœboid corpuscles, and the true *Amœbæ* is very remarkable in the class of animals which he has selected for study; he is of opinion that they ought to be able to lead us to a resolution of the important question, Does the term *amœboid* express any accidental analogy, or a deep-seated resemblance?

The perivisceral fluid of *Echinus sphæra* or *Toxopneustes lividus* is of a slightly greyish-red tinge, with a musk-like exhalation. The

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* Bull. Mus. Comp. Zool. Camb., viii. (1880) pp. 69–84.

† Arch. Zool. Expér. et Gén., viii. (1880) pp. 483–97.

specific gravity is 1026, or the same as that of sea-water; it has an alkaline reaction, and contains a minute quantity of albuminoid matter. It rapidly undergoes coagulation, and the corpuscles form a clot, which, considerable at first, contracts very rapidly.

The white corpuscles are of two kinds. One is that of an amœboid nucleated cell, the protoplasm of which is finely granular; the pseudopodia are long, filiform, and branched, or are united with one another to form rings, and the two kinds of pseudopodia may be found in one corpuscle. Extreme types appear only to be developed during the gradual death of the animal. The annular disposition of the pseudopodia appears to be characteristic of the Echinodermata; Semper has noticed it in the Holothuroida, and Mr. Geddes has observed it in Ophiurida and Comatula, but never in any other invertebrates.

When the corpuscles unite, they do so thus: the pseudopodia of one corpuscle touch and unite with those of one of their neighbours, and then the corpuscles approach one another and soon form a single homogeneous mass. This new body seizes on all the corpuscles with which it meets, incorporates them, and grows like a rolling snowball. Thus there are produced vast plasmodia, which soon become differentiated into a transparent homogeneous ectosarc and a granular endosarc. The latter contains foreign bodies.

This plasmodium, or composite amœba, now takes on a new form of activity; the ectosarc gives off pseudopodia of extraordinary length, which ramify and anastomose. These pseudopodia are generally filiform.

If we seek to compare the corpuscles of organized fluids with the Protozoa, we must not limit ourselves to the ordinary *Amœba*, but must take into account such forms as *Protomyxa* or *Myxomycetes;* when we do this, we get the following comparative table:—

Corpuscles.	*Myxomycetes.*
1. Development by transverse division.	1. By endogenous division.
2. Flagellated cell (mastigopod).	2. Mastigopoda.
3. Amœboid cell (myxopod).	3. Myxopoda.
4. Mobile plasmodium (produced under fresh conditions).	4. Mobile plasmodium.
5. Immobile sphæroid.	5. Immobile sphæroid.
6. Death.	6. Encystation and fresh division.

The author is of opinion that the theory which looks on the amœboid character as being a fundamental character of the animal cell is fully justified.

Coming now to the second and rarer type of white blood-corpuscle, we find it to be larger and to be filled with large spherical refractive granules, which obscure the presence of the nucleus. The delicate pseudopodia are short; they resemble the mucous cells which Semper detected in the Holothurians, and they are the coarsely granulated corpuscles in vertebrated as well as in invertebrated animals.

The most interesting corpuscles are those coloured brown, which the author has never detected in any other Echinoderms than the

Echinoidea and some Holothurians. Found as cells containing yellowish-green spherules in the blood-vessel of the intestine and in the ambulacral saccules, they vary greatly in size. When they unite into larger masses, the addition of acetic acid reveals the presence of a surrounding layer of non-nucleated protoplasm. Larger brown spherules are also found intermixed with these, and they become more and more deeply pigmented and get to resemble the coloured corpuscles, taking on as they do the coarser granulation and the irregular form. In fine, there is every phase of development between the greenish-yellow and the brown corpuscles; so that we have here an exception to the general rule, that in the Metazoa every cell arises from the transverse division of another cell.

As to the function of these bodies, there is some reason for suggesting that it is respiratory; the colouring matter, which is instable, is highly ferruginous; this instability is very remarkable in *Spatangus purpureus.* Purple, blue, green, olive, or yellow corpuscles may be found in the blood-vessels; some of these are, at any rate, nothing but altered brown corpuscles, and there can be no doubt but that the purple colour of the *Spatangus* is due to a decomposition of the brown matter.

Contrary to the opinion of Hoffmann, Mr. Geddes thinks that spermatozoa never escape naturally into the perivisceral cavity. The infusorian parasites which are so abundant in the cavity of *Strongylocentrotus lividus* would appear to reach it by some accidental lesion of the walls of the intestine.

The irregular bodies sometimes found in the ambulacral saccules are shown to be nothing more than fragments of muscular fibres; it is incorrect to imagine, as Williams and others have, that the perivisceral fluid, the ambulacral fluid, and the blood contain the same histological elements; the three systems are really independent.

Pedicellariæ and Muscles of Sea-Urchin.*—Messrs. P. Geddes and F. E. Beddard have recently studied the pedicellariæ, which have of late received fresh attention from several good observers. They find that in the snake-headed form of pedicellaria the muscles uniting the head to the stem are not attached directly to the calcareous parts; most of them terminate in a series of loops outside the latter. Two fasciculi are continued beyond the rest, mingle with the semicircular muscles of the valves, and end freely in a tuft of meshes in the middle of the triangular valve-muscle. A peculiar reticulated structure, not acted upon by dilute acetic acid, and lying in the intervals of the muscular fibres just described, is probably elastic and acts as a ligament, opening the valve when the adductor muscles are not contracted. In the tridactyle and gemmiform pedicellariæ these ligamentary structures are very delicate, and the muscles of the outer end of the stem are inserted on the calcareous parts instead of forming loops.

Outside each valve of the gemmiform type lies a gland covered by two layers of muscular fibres and a layer of cylindrical epithelium.

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* Comptes Rendus, xcii. (1881) pp. 308–10.

This form of pedicellaria constitutes, perhaps, an urticating organ, or, as Sladen believes, secretes mucus.

The various statements as to the striation or non-striation of the muscles of Echinoderms are explained by an examination of those of *Echinus*, in which both conditions may be found in the same muscle at different times; sometimes even the same fibre is striated in one part and not in another. The presence of striæ is coincident with that of constrictions of the fibres, and it is probable that it is connected with their contraction.

New Asteroidea.*—Professor Perrier has a note on the starfishes collected by the steamship 'Blake,' and entrusted to him for description by Professor Alex. Agassiz. Some of these, such as the curious *Hymenodiscus*, he has already described. *Goniopecten* would seem, in the structure of its skeleton, to belong to the Goniasteridæ, but the form of its ambulacral tubes and the characters of its "teeth" are exactly those of *Astropecten*. Four species of this genus have been distinguished. *Radiaster* (taken at a depth of 1800 m.) is a large Asterid, which has the spines of *Solaster*, the marginal plates of *Goniaster*, and the ventral plates resembling those of some *Asterinidæ*. *Ctenaster*, which is three-tenths of a metre in diameter, and specimens of which were taken from a depth of 3500 m., has six arms, and resembles a gigantic *Ctenodiscus* deprived of its ventral plates, and so far resembling the *Echinasteridæ*. *Marginaster* is a genus formed for small pentagonal creatures, which resemble *Asterina*, but have Goniasterine marginal plates.

Archaster is very numerously represented, for there are of it seven species, one of which, *A. mirabilis*, is very variable in form, and is represented by more than one hundred specimens. There are eleven species of *Goniasteridæ;* the new genus *Anthenoides* is intermediate between *Anthenea* and *Pentagonaster*.

Several new forms of pedicellariæ, an organ which, as is well known, has been the especial object of M. Perrier's studies, were discovered. *Pentagonaster ternalis* has three, instead of the ordinary two branches. Luidiæ with four have been found. *Archaster mirabilis* has on some of its ossicles a complicated "comb" of spines, and is interesting as proving the homology of the pedicellariæ with the spines, or even the large calcareous granules of the skeleton of Asterids or Echinids.

A remarkable agreement between the number of the tentacles, the structure of the mouth, and the form of the pedicellariæ would seem to lead to the division of the Asterida into two distinct families.

M. Perrier's very short notice is sufficient to prove that a very considerable addition is being made to our knowledge of these forms.

Structural Feature, hitherto unknown among Echinodermata, found in Deep-sea Ophiurans.†—Professor Lyman describes two new genera, *Ophiotholia* and *Ophiohelus*, which are characterized by the

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* Comptes Rendus, xcii. (1881) pp. 59–61.

† Anniv. Mem. Boston Soc. Nat. Hist. (1880) p. 1.

possession of bunches of minute spines, enclosed in a thick skin-bag, and resembling in form "long-stemmed agarics, or parasols with small shades." They are, however, more remarkable for their arrangement than for their form. This was in two or even three parallel vertical rows, instead of the "unvarying single row of articulated spines which is found in all known living Ophiurids." As the author points out, it is not necessary to inquire whether they are spines or pedicellariæ, inasmuch as pedicellariæ are only modified spines; "but it may be said that their supplementary character and abnormal shape give these parasol spines the position of what used to be carefully distinguished as pedicellariæ."

Ophiotholia appears to be closely allied to *Ophiomyces;* both the new genera would seem to be lowly in character, for they have no radial shields, are but imperfectly calcified, and retain throughout life the division of their arm-bones into two longitudinal halves.

The author is of opinion that, as one species was dredged at 82 fathoms near the Barbadoes, and the other from 1350 fathoms near the Fijis, we have only to consider the differences of locality, light, pressure, and temperature, to develope some scepticism as to the influence of "environment" in determining structure.

Professor Lyman at the same time describes three new genera:—*Ophiocymbium*, *Ophiochyton*, and *Ophiambix*. Altogether 167 new species and 20 new genera of Ophiurids and Astrophytids were brought home by the 'Challenger.'

Cœlenterata.

Early Stages of Renilla.*—Mr. E. B. Wilson has been studying the development of this Pennatulid, and here gives a preliminary account of his investigations. The larva, which exhibits a well-marked bilateral symmetry, is ciliated, and at first swims actively. The first pair of zooids is indicated by two slight elevations; the septa are unequal in length, but bilaterally symmetrical. After ceasing to swim about freely, eight pinnate tentacles become developed at the free end, the lateral zooids divide into chambers, and a median zooid appears on the upper side, and in front of the lateral zooids. This ultimately becomes the central zooid ("Hauptzooid" of the German describers), through which the water of the colony is chiefly discharged. Some time before this the characteristic spicules put in their appearance. At a still later stage we find the lateral zooids with well-developed tentacles, and there are also four new pairs; all these develope into sexual zooids, and in addition to them, and after a mode of development exactly the same, there appear rudimentary zooids. "The subsequent development consists in the growth of these sexual zooids, the constant development of new ones in the angles between contiguous pre-existing sexual zooids, and the appearance of a series of rudimentary zooids on the upper side of each sexual zooid. And at length each rudimentary zooid, with the exception of the median 'Hauptzooid,' multiplies to form a group of similar zooids." It is

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* Amer. Journ. Sci., cxx. (1880) pp. 446-50 (1 pl.).

curious to observe that the mode of budding exhibited by these last is like that of the entire colony. As the so-called "Hauptzooid" is not the primary polyp, but a secondary zooid, the term is a misnomer. Finally, we have to note that the posterior part of the body of the primary polyp persists as the peduncle of the colony.

Development of Campanularia angulata.[*]—M. J. Fraipont has a fuller account, illustrated by three plates, of his investigations on this subject, of which an account has been already given.[†]

Development of the Ova of Eudendrium.[‡]—Dr. N. Kleinenberg is not satisfied with the evidence adduced by Goette[§] as to the endodermal origin of the ova of this Hydroid; he believes that the ectodermal cells may wander into the endoderm. He has always seen the generative cells derived from the ectoderm; where the difficulties of observation have prevented this, they have likewise prevented him from coming to any definite conclusion at all. In no case has he proof of endodermal cells being converted into generative cells. Against the definite results of E. van Beneden, he can only say that the use of acetic acid is very likely to lead to wrong conclusions. He cannot understand how Weismann failed to detect the presence of ovarian cells in the ectoderm, unless he examined the animal after its most active stage. Many Hydroids exhibit a well-marked periodicity in the development of their generative products; those that are formed during the intermediate periods are often abortive or variously abnormal. Developed embryos, unfertilized ova, ripe spermatozoa, and young sperm-cells may all be found in the same bud. *Eudendrium* is most active reproductively at the beginning and at the end of summer.

Porifera.

Sponges of Russia.[‖]—Dr. W. Dybowsky, who seems to have obtained a large amount of material for the study of this subject, has made extensive use of dry specimens, finding that this method is quite sufficient for systematic determinations of the siliceous forms, and considering, as he does, that in the *Halichondriæ* (Schmidt) the skeleton is the only part which is important in this respect. The plan adopted for preparing dried sponges for the Microscope, is to boil a thin section in alcohol, until the liquid becomes cloudy owing to the incipient solution of the parenchyma; concentrated solution of potash (more or less, according to the proportion of horny matter in the skeleton) is now added, and the whole warmed until of a brown colour; the fragments are then removed and boiled again in alcohol, by this means much of the parenchyma is removed; the residue is teased and stained for a few minutes in alcoholic solution of eosin, which colours only the remaining horny substance; creosote, or oil of cloves, or a mixture of both, is used to render the preparation transparent, and it is then mounted in Canada balsam. For the study of

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[*] Arch. Zool. Expér. et Gén., viii. (1880) pp. 433–67 (3 pls.).
[†] See this Journal, iii. (1880) p. 459.
[‡] Zeitschr. wiss. Zool., xxxv. (1881) pp. 326–32.
[§] See this Journal, iii. (1880) p. 812.
[‖] Mém. Acad. Impér. St. Petersburg, xxvii. (1880) No. 6, pp. 1–71 (4 pls.).

the parenchyma the same plan is adopted, omitting the potash. For the isolation of spicules, the method recommended by Bowerbank in his monograph of British sponges is followed, with the addition of one or two washings of the dissolved mass of spicules in alcohol previous to mounting; if a skeleton is especially refractory owing to its large proportion of horny matter, it is teased, and the loosened spicules are then mounted.

The systematic part of this work is devoted to the sponges of Lake Baikal,* which are shown to be much more numerous and interesting than any previous observer has ever found them to be; and to a re-description of the species of *Veluspa*, *Reniera*, and *Metschnikowia*, described chiefly by Miklucho-Maclay and Grimm, from the White, Black, and Caspian seas. The *Spongillidæ* are reserved for a future memoir.

The Baikal sponges were obtained from depths of from 2 to 50 metres, or as dead beach specimens; the greater depths of the lake, extending to as much as 1370 metres, are still unexplored.

All the forms (four in number, besides varieties) belong to a new genus, *Lubomirskia*, based on the old species of Pallas, *Spongia baicalensis*, and characterized as follows:—Shape very various; the skeleton consists of a set of fibres perpendicular to the surface, united by short horizontal ones. The fibres are almost wholly composed of siliceous spicula, which lie 6–14 thick in the perpendicular, and 1–6 thick in the horizontal fibres; the spicula are either fusiform or bacillar, with rounded ends; their ends are sometimes minutely spined. The flesh spicules are irregularly scattered and smooth, but otherwise differ from the skeleton forms only by their inferior dimensions. Pores scattered over the entire surface; oscula various in shape, but almost always of complicated outline. Reproduction perhaps by ova; no gemmules occur as in *Spongilla*. This interesting genus differs from *Spongilla* in the shape of the oscula, in that of the spicula, which are not of the peculiar fusiform type of *Spongilla*, and in the absence of gemmules. The type species, *L. baicalensis*, is stated to vary in shape from branching to simple, horizontally-extended, cylindrical forms; the latter are younger stages of the former. The proportions between the dimensions of the stem and branches in different specimens are tolerably constant, as also are the characters of the pores and oscula. The perpendicular fibres are 0·11 mm. thick.

To show the nature and extent to which variability occurs in the size of spicules in sponges of this kind, the measurements of ten skeleton-spicules of the typical form of this species may be given.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
Length	·222	·213	·210	·201	·243	·201	·189	·183	·183	·168
Maximum diameter	·021	·018	·009	·009	·015	·015	·015	·015	·024	·021
Diameter immediately before the end ..	·009	·009	·006	·006	·012	·009	·006	·006	·009	·006

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* Cf. a preliminary account in Zool. Anzeiger, i. (1878) pp. 30 and 53.

(From this it will be seen that the length may vary from 0·168 to 0·243 mm., the maximum diameter from 0·009 to 0·024, and that there is some approximation to an inverse proportion between the length and the breadth.) Four varieties of the sponge are found; the skeleton spicules of the first (*var.* α) are more thickly spined at the ends than in the middle; *var.* β has the middle of the spicule devoid of spines, and the spicule is thicker; *var.* γ has its spicules still thicker, but spined only at the extreme ends; in *var.* δ they agree with those of the preceding form but are smaller. Their chief proportions in the four varieties are instructive:—

	Var. α.	*Var.* β.	*Var.* γ.	*Var.* δ.
Length	·18 to ·231	·198 to ·231	·270 to ·339	·165 to ·219
Maximum diameter ..	·012 „ ·015	·018 „ ·024	·015 „ ·03	·015 „ ·024
Diameter just before end	·006	·006 „ ·009	·006 „ ·015	·006 „ ·009

L. bacillifera is the first new species; it is found in shallow water on the south-west side of the lake. It differs from *baicalensis* in its irregular flattened form, in the slender proportions of the perpendicular fibres, which contain only four to six spicules in their thickness, and the skeleton spicules are bacillar and spined and vary in length from 0·225 to 0·27 mm. and in thickness from 0·021 to 0·027. There are three varieties, differing more or less in the form and proportions of the oscula and spicules.

L. intermedia is also a flat encrusting form; it presents characters of transition to *Spongilla.* The horny substance is but slightly developed; the skeleton spicules are bacillar, with abruptly pointed ends and covered with spines which are most abundant at the ends; they vary in length from 0·162 to 0·222 mm. and in diameter from 0·012 to 0·024 mm.; in the varieties they are somewhat longer and generally thinner.

L. papyracea is encrusting, but very thin; it has no vertical skeleton-fibres; the skeleton spicules are bent and bacillar, with rounded ends, and spined all over; the horny substance is delicate; the skeleton spicules vary in length from ·12 to ·144 mm., and in diameter from ·012 to ·021 mm.

With regard to the aggregation of sponge-forms from very widely separate localities united by Miklucho-Maclay under the name *Veluspa polymorpha,* Professor Dybowsky comes to the conclusion that two of these so-called varieties are species distinct from the rest, and belonging, the var. *gracilis* to the genus *Reniera,* the var. *arctica* to *Pachychalina* (being identical with *P. compressa* Schmidt); a third variety (*baicalensis*) is based on *Spongia baicalensis* Pallas, assigned above to *Lubomirskia*; the remaining eight varieties of Miklucho-Maclay are now grouped under the single generic and specific designation, *Veluspa polymorpha. Veluspa,* as freshly characterized, is shown to be allied to *Clathria* Schmidt, and *Trachya* Carter. With *Clathria* it agrees in the peculiar form and the two sizes of its singly-pointed spicules, but it differs from it in having those of the smaller form aggregated into a special superficial mass, instead of remaining isolated and projecting into the spaces. With *Trachya* it agrees in the latter point, but the large spicules are singly not doubly pointed, and form a network instead of a number of aggregations.

Just as the Baikal Lake has a genus of sponges peculiar to it, so has the Caspian Sea,—the genus in this case is *Metschnikowia* of Grimm, represented by the two species *M. tuberculata* and *intermedia* of Grimm and by a *Reniera flava* of the same author, now referred to the genus by Dybowsky. It is most nearly related to the widely distributed marine genus *Reniera*, differing from it chiefly in the spination of its doubly-pointed spicules.

In all, the Russian empire is said to possess * thirty-five species of marine and eight of fresh-water sponges, *Spongilla lacustris* occurring in both categories. Of these, the Caspian Sea produces an *Amorphina* besides the species of its endemic genus *Metschnikowia;* the Black Sea possesses one *Reniera*, the White Sea twenty-three species, of which six are allies of *Reniera*, and six are Calcisponges; there are also a Horny Sponge, three Renierid forms, and a Chalinid. The Gulf of Finland produces the otherwise fresh-water *Spongilla lacustris.* Of the fresh-water regions, the fauna of Lake Baikal has been described above; the smaller neighbouring Pachabicha Lake produces a peculiar *Spongilla* besides *S. lacustris*, while the only species found in the six remaining examined localities are *S. lacustris* and *Trachyspongilla erinaceus* and *Ephydatia* (*Spongilla*) *fluviatilis.*

Protozoa.

Cilia of Infusoria.†—In his recent essay on Cilia, Professor T. W. Engelmann makes some brief but noteworthy references to the Infusoria. Notwithstanding the very high specialization of these "unicellular" organisms, he could not detect among them intracellular fibres subtending the cilia, such as those which occur in the ciliated epithelium of Lamellibranchs. Of this kind are not the muscular striæ of *Stentor*, alleged by Simroth to be in connection with the cilia beneath which they course. This connection Engelmann could not confirm. Certain it is that the ciliary motions of *Stentor* are independent of the general contractions of its body.

Encysted animalcules, still capable of swimming, offer very instructive appearances, because of the restrictions which their cilia encounter (E, p. 527).

The aboral tiara of Vorticellidæ which have left their stalk has a peculiar structure, favourably studied in *Carchesium polypinum.* The base from which this wreath arises forms a raised ring, which, when well developed, is about 2·5 μ broad and 0·5 μ high. The substance of this band, continuous with the ectoplasm, is strongly refracting,

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* This number has since been considerably added to by Czerniavsky's memoirs, in the Bull. Soc. Nat. Moscou, on the sponges of the Black and Caspian Seas. One of the species mentioned by Dybowsky has since been shown to be no sponge.

† See reference under "Ciliated Cells," *ante*, p. 221.

just as is the operculum of ordinary ciliated cells. In common with the perisome, the aboral band is not invested by the adjacent cuticle. Under varied illumination, it displays two apparently distinct systems of oblique striæ. More refined analysis shows that we have here really to do with rows of granules upon which the cilia are elevated, and which may still be seen in specimens whose cilia have fallen off.

Engelmann also compares the characteristic border of ciliated cells elsewhere with the broad, flat, strongly refractive supports of the adoral clusters of cilia (membranules of Sterki) found in the Oxytrichina and Euplotina—"at least, so far as these stand on the ventral aspect."

Stylonychia mytilus has unquestionably a system of ventral fibres trending from near the middle line, beneath the ectoplasm, to the two conspicuous series of large admarginal cilia, which aid so powerfully the motions of this huge animalcule. But these fibres are not like the fibres of ordinary ciliated cells, nor are the lashes which they supply cilia, properly so called. The lashes are complex appendages, remote from one another, moving independently under the control of their possessor. Each has its own fibre, which is pale, soft, homogeneous, and not more than $0 \cdot 2\,\mu$ across. The fibres are parallel, and so delicate that they can only be seen for a short time in specimens starved during some hours in filtered water, and then killed in osmic acid. Are not these fibres truly nerves? Why, asks Engelmann, should not the higher Infusoria possess a nervous system? May not more exact researches soon decide this question in the affirmative? Has not *Panophrys flava* eyes? If not so, what is the function of the watchglass-shaped organ with its pigment-spot?

BOTANY.

A. GENERAL, including Embryology and Histology of the Phanerogamia.

Morphology of the Ovule.*—From a fresh examination of phylloid ovules (*Alliaria* and others), J. Velenovsky confirms the generally accepted theory that the ovule is the result of metamorphosis of a segment of a leaf or of a carpel, with its metablast or nucellus. The inner integument is composed of the middle part and central lobe of the ovular leaflet, the nucellus being an outgrowth on the upper side of the ovular leaflet or inner side of the inner integument, which in the normal ovule includes the base of the integument-cup.

Embryogeny of Lupinus.†—Professor E. Strasburger has examined the development of the embryo in *Lupinus Barkeri*, *polyphyllus*, *subcarnosus*, *leptocarpus*, *angustifolius*, and *luteus*, and has found the

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* 'Flora,' lxiv. (1881) pp. 33–45 (1 pl.).

† Bot. Ztg., xxxviii. (1880) pp. 857–68 (pl. xii. figs. 23–64).

processes to correspond closely to those already described by Hegelmaier,[*] the details being given in each case. He found the alcoholic preparation of young ovules not favourable for observation, disorganized conditions only being presented in the interior of the embryo-sac. With fresh material, fortunate sections sometimes exhibited the phenomena very clearly; the best results were obtained with the assistance of 1 per cent. chromic acid. The ovary was not opened before laying in the solution. After several days, it was washed with distilled water, and placed in a mixture of glycerine and alcohol. All the preparations were tinged with borax-carmine.

Embryology of Orchis maculata.[†]—From an examination of the structure and development of the embryo in this species, M. Montéverdé confirms the statement of Pfitzer (in opposition to that of Hofmeister and Fleischer), that it proceeds, not from a single cell, but from three or four of the cells of the suspensor, in which longitudinal walls are produced in the form of a cross. Each of the layers formed in this way divides into four central and four peripheric cells; the latter are not equivalent to the dermatogen. The suspensory cell which is nearest to the embryo, the third or fourth of the primordial cells, is the hypophysis.

In its earliest stage the embryo of *Orchis maculata* is composed of two cells of unequal size, an upper smaller, and a lower cell nearly double its size. This last is divided by a second transverse wall into a smaller middle and a larger lower cell; these two walls are usually inclined to one another. The first longitudinal division then makes its appearance in the upper cell, dividing it into two equal, or less often unequal parts. A new transverse division next appears in the lower cell, and at the same time a second longitudinal division in the middle cell. In the two lower cells the succeeding transverse divisions are formed in an intercalary manner, so that four cells are produced, each of which is divided afresh into two by transverse walls, though this is not always the case. Of these eight cells, the seven lower ones constitute the suspensor, and subsequently perish, while the uppermost takes part in the formation of the embryo.

A comparison of the first stages of development of the embryo of *Orchis maculata* with those of other Monocotyledons, for example, *Brachypodium*, as described by Hanstein, shows a very close resemblance, not only in their general character, but also in the relative position of the two first transverse walls, in the appearance of the two longitudinal walls of the two upper cells, and finally in the fact that one of the cells often assumes the appearance of a terminal cell.

The third cell, which is usually regarded as the hypophysis, also takes its share, with the two superior cells, in the formation of the embryo. As a rule, this cell, after having divided by a transverse wall, produces in its upper part one or two longitudinal divisions arranged in a cross, and always remains in this state until the seed is mature.

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[*] See this Journal, iii. (1880) p. 979.

[†] Bull. Acad. Imp. St. Petersburg, xxvii. (1880) pp. 326–35.

A certain difference must be noted between the formation of the embryo of *Orchis maculata* and that of *Alisma Plantago*, which is regarded as the type of monocotyledons. In the former case the embryo, composed at the outset of three cells, is formed from two superior cells, and partly from the inferior cell; in the latter case it is formed from the superior and partly from the middle cell. But in the formation of the first longitudinal walls arranged in a cross, the resemblance is complete.

For rendering the embryo transparent, M. Montéverdé employed spirits of wine, alkali, and acetic acid. The youngest were placed in a 10 per cent. alkaline solution, usually for not more than two days.

Course of the Pollen-tube in Angiosperms.*—M. Detmar has made a detailed examination of the structures by means of which the passage of the pollen-tube into the ovary and into the ovule is facilitated. The very large number of cases examined he divides into six classes, advancing from the simpler to the more complicated.

1. In Gymnosperms the contrivances which conduct the pollen-tube to the corpuscula are very simple, the course being direct, and usually very short. The pollen-grains fall directly on the nucellus, the tissue of which, as far as the corpuscula, is very loose. In *Welwitschia* the corpuscula develop into long tubes within the nucellus, meeting the pollen-tubes. The Loranthaceæ exhibit a very simple structure in their conducting apparatus, analogous, but not homologous, to that of Gymnosperms. In *Viscum album* there are from two to four embryo-sacs, above which the nucellar tissue is also very loose. In *Loranthus bicolor* the embryo-sacs meet the pollen-tubes, like the corpuscula of *Welwitschia.*

2. The course of the pollen-tube in Angiosperms depends, in the first place, on the position of the micropyle. The most favourable structure is when the micropyle lies immediately beneath the base of the style, of which *Polygonum divaricatum* furnishes a good example. The conducting tissue of the three styles projects in the form of a cone into almost immediate contact with the apex of the ovule; as is also the case in *Daphne Mezereum.* In the Compositæ (e. g. *Senecio Doria*) the conducting tissue of the style consists of two closely adjacent lines, which separate when they reach the cavity of the ovary, passing down the two sides, and meeting again beneath the basilar anatropous ovule. They consist of strongly mucilaginous cells, which are often isolated on transverse section. The micropyle is entirely filled with mucilage. In Plumbagineæ the long coiled funiculus brings the micropyle of the anatropous ovule immediately beneath the base of the styles. A cone of conducting tissue descends from the base of the five united styles nearly to the ovule. The Chenopodiaceæ, with their campylotropous ovules, display a similar contrivance.

3. The process is not so simple where the micropyle does not lie immediately beneath the base of the style. In *Ricinus* the ovary is trilocular, each loculus containing a single anatropous ovule. The conducting canal of the style branches within the ovary into three;

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* Jenaische Zeitschr. Naturwiss., xiv. (1880) pp. 530–66.

these open into the three loculi immediately above the point of insertion of the ovules, so that the pollen-tube is conducted straight to the funiculus, which is swollen on the upper side, and densely clothed with papillæ, which project like a tuft above the micropyle. These, like the papillæ of the stigma, contain a red pigment. In *Euphorbia helioscopia* the papillæ are densely filled with protoplasm, and temporarily with large starch-grains. The nucellus projects into the micropyle, and is in immediate contact with these papillæ. Similar arrangements occur in *Mercurialis annua*, *Linum usitatissimum*, and *Citrus aurantium.* In *Phytolacca* the funiculus is surrounded by a crest of papillæ, which reach the mouth of the micropyle.

4. In *Mahonia aquifolium* the unilocular ovary contains four or five basal anatropous ovules. Both the stigma and the stylar canal are clothed with papillæ. Only the upper part of the placenta is provided with papillæ; in the lower part they pass into small cells, distinguished by their metaplasmic contents, and cuticularized. The micropyle is at some distance from the placenta, and the further conduction of the pollen-tube is undertaken by the funiculus, the epidermal cells of which are of a similar nature to those of the placenta. A similar structure occurs in Liliaceæ (*Ornithogalum nutans* and *pyramidale*, and *Anthericum Liliago*) with their trilocular ovary, each loculus containing several ovules. In *Verbascum Thapsus* the very conspicuous mucilaginous layer overlays both placentæ, and the somewhat thickened funiculi. In *Nuphar luteum* the whole inner surface of the ovary is covered with a granular mucilage. In the Cactaceæ the very long coiled funiculus is covered over its entire ventral surface with long papillæ. In Cruciferæ (*Lepidium virginicum* and *sativum* and *Iberis amara*) we find similar contrivances.

5. In Aroideæ the ovules are usually orthotropous, but the position of the micropyle often appears very unfavourable to the entrance of the pollen-tube; but in *Atherurus ternatus* the arrangement is much more simple, and resembles that in *Polygonum.* In *Arum maculatum* the single parietal placenta bears four or six orthotropous ovules. A short canal extends from the style into the cavity of the ovary, round the mouth of which, as well as covering the placenta, are unicellular or multicellular papillæ of various length. From these is developed a mucilage which, at the time of blossoming, surrounds the mouth of the canal and the ovules, reaching to the micropyle. In *Philodendron pinnatifidum* a similar structure is found. *Acorus Calamus* is distinguished by the upper margin of the integument, near the micropyle, being also developed into a long papilla.

6. The least favourable structure for the conduction of the pollen-tubes is presented by the free central placentation. In *Calla palustris* the mouth of the stylar canal and each ovule is completely surrounded by a tuft of papillæ, between which is a large drop of mucilage; and a similar structure occurs in *Luzula pilosa.* In Caryophyllaceæ (*Saponaria ocymoides* and *Lychnis vespertina*) are four rows of campylotropous ovules, the micropyles in each pair of rows always facing one another. Between these rows are two conducting bands, which bear mucilaginous papillæ. In Primulaceæ (*Anagallis*

arvensis and *Primula sinensis* and *elatior*) the free central placenta is united with the stylar canal by a cone of conducting tissue projecting from the placenta into the canal. The pollen-tubes, after descending the stylar canal, are taken up by this cone, and conducted to the micropyle over the papillose surface of the placenta.

The following may be stated as the general results reached by Detmar's observations. The growing pollen-tubes receive their formative materials from the mucilaginous and amyloid substances secreted by secreting organs on the stigma, and in the stylar canal and interior of the ovary. These secreting organs are more or less papillose, varying in form from a small projection to a long hair, and are usually unicellular, though sometimes multicellular. The stigmatic papillæ are, as a rule, longer than those of the ovary, since they also provide a detaining apparatus for the pollen; but their contents are apparently identical with the metaplasm of the colleters and nectaries. Besides providing nutrition for the pollen-tubes, these papillose structures furnish also a conducting tissue, to guide the pollen-tube, when it has reached the cavity of the ovary, to the micropyles of the ovules. The position of this conducting tissue within the ovary depends on that of the micropyles. A conducting tissue of a similar nature may occur on the internal walls of the ovary, on the funiculus, and even on the integuments of the ovule, the same physiological functions being performed by structures of very different morphological value. Seeing that this tissue reaches up to the very micropyle itself, and that it only can supply the pollen-tube with the nutriment it requires, it follows that the entrance of the pollen-tube into the ovule is a purely mechanical phenomenon, and does not depend on any mysterious relationships between the pollen-tube and the embryo-sac.

Nucleus of Vegetable Cells.*—Treub states that in the older cells in the neighbourhood of the vascular bundles of the leaf-stalk of *Ophioglossum vulgatum* and *Botrychium Lunaria* are nuclei, which are of no regular form, but have more or less deep indentations, causing them to be lobed or constricted. The constriction sometimes goes so far that in optical section the nucleus appears completely divided in two; but focussing always shows the parts to be united by a thin strip, no actual division of the nucleus taking place. But in other cases—like the large cells of the internodes of *Chara*, as Schmitz and the writer have already observed—a complete division is effected. A fresh illustration of this "fragmentation," in contrast to normal division, was observed in the endosperm-cells of the embryo-sac of *Imatophyllum cyrtanthiflorum*, where various stages of the process may be observed in the same preparation.

Not only in the nuclei of multinucleated cells, and in free cell-formation, does a simultaneous division of nuclei take place, but in an entire group of cells in the endosperm of *Imatophyllum cyrtanthiflorum* the division of the nuclei takes place simultaneously. This

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* Arch. de Biol., iii. (1880) pp. 393-404 (1 pl.). See Bot. Centralbl., ii. (1881) p. 106.

phenomenon was observed especially in the filaments in which the antherozoids of Characeæ are produced, the nuclei of as many as thirty of these cells being often found in the same stage of division, or with scarcely an appreciable difference. In this object the strong contraction of the nucleus could also be observed which precedes the formation of the nuclear plate. The author compares the processes of division of the nuclei of multinucleated cells with the simultaneous divisions, alternating with periods of rest, in cells arranged in rows, layers, or groups.

The author also figures the results of observations on the vegetative cells of *Chara fragilis*, for the purpose of determining whether the septum owes its origin to a cellulose-ring springing from the side-wall, as in *Spirogyra*, or whether, as in vascular plants, a plate of cellulose is formed between the two young nuclei, which continues to grow at its margin until it finally touches the side-walls, or in some other way. It was proved that the septum is formed precisely as in vascular plants. Between the cell-filaments which together constitute the barrel-shaped body, a cell-plate appears at a very early period, never a parietal ring. In some cases, as in vascular plants, a still imperfect cellulose-wall could be observed in the cell-plate, which subsequently extended to the cell-wall.

Cell-nucleus in the Secretion-receptacles and Parenchymatous Cells of the Higher Monocotyledons.*—By the application of hæmatoxylin, F. Johow has examined the nucleus in the following descriptions of cells:—The cells containing raphides of *Tradescantia*, several Liliaceæ and Amaryllidaceæ, *Anthurium sagittatum*, and *Orchis maculata*; the glandular cells of *Anthurium sagittatum* and *Philodendron cordifolium*; the laticiferous and resin-passages of *Allium Cepa* and *Aloe*; the tannin-passages of *Acorus Calamus;* and the segmented laticiferous vessels of *Anthurium sagittatum.* The nucleus was in these cases always situated in the parietal layer of protoplasm. They may be divided into three classes: the most normal are the tannin and laticiferous vessels, where the nucleus has quite the normal structure; next, the laticiferous and resin-passages (*Schläuche*), where the nucleus is enlarged; while the greatest diversity from the normal type is exhibited by the vessels containing crystals, where the nucleus has undergone considerable change in form and structure, and contains vacuoles. This is especially the case in *Hyacinthus* and *Tradescantia.* In the vessels containing raphides of *Tradescantia virginica* the nuclei vary greatly in form; they may be disk-shaped, roundish, angular, elongated, rod-shaped, or sickle-shaped.

The author is of opinion that the protoplasm and nucleus in these vessels and passages are still in a living condition.

Johow further asserts the presence of several nuclei in the cells of the tissue of some Monocotyledons, and describes them minutely in the case of *Tradescantia*, *Allium Cepa*, and *Orchis macu-*

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* Johow, F., 'Unters. über den Zellkern in den Secretbehältern u. Parenchymzellen der höheren Monocotyledonen,' Bonn, 1880. See Bot. Ztg., xxxviii. (1880) p. 826.

lata. They are formed by the original nucleus of the cell becoming constricted, and then breaking up into two or more pieces, without any change of structure being visible in the interior. This takes place only in cells of considerable age, the protoplasm of which is still in circulation and contains chlorophyll and starch. The author prefers for this phenomenon the term "direct division" of the nucleus, rather than "fragmentation," as proposed by Van Beneden.

Multinucleated Cells.*—Professor E. Strasburger has followed up the observations of Hegelmaier † and Johow ‡ on the presence of several nuclei in the cells of the embryo of Leguminosæ and in the older cells of Monocotyledons, confirming them in all essential points. He was, however, unable to detect more than one nucleus in the cells of *Hemerocallis flava*, *Canna indica*, *Sagittaria sagittæfolia*, *Sparganium ramosum*, *Alisma Plantago*, *Butomus umbellatus*, or *Nothoscordon fragrans*. *Orchis pallens* affords a very favourable object for observation. The preparations were either fresh or in alcohol; in the latter case coloured by borax-carmine. To detect fragmentation of the nucleus, acetic acid with 1 per cent. methyl-green was employed, the fixing and tinging properties of which are very valuable.

In the tissue-cells of Dicotyledons fragmentation of the nucleus appears to be a less common occurrence than in Monocotyledons. It was observed in the pith of *Tropæolum majus* and of species of *Nicotiana*, but only in very old cells shortly before the disorganization of the nucleus. As has been already observed also by Treub and Hegelmaier, the phenomenon is very easily observed in the suspensory cells of the embryo of Vicieæ, and of the section *capnoides* of *Corydalis*.

According to Strasburger, the two phenomena of the division and fragmentation of the nucleus are not identical. Division of the nucleus takes place in cells with active vitality, and under the influence of the surrounding protoplasm; fragmentation, on the contrary, is a process belonging to the nucleus only, which does not set up until the influence upon it of the surrounding protoplasm has ceased. It obviously leads, in many cases, to a rapid disorganization of the nucleus; in other cases, however, this does not follow rapidly, and the cell then remains for a long time in a multinucleated condition. A very favourable illustration of fragmentation is presented by the internodal cells of *Chara*. When fragmentation of the nucleus has taken place, the cell-protoplasm would appear to be no longer capable of division. Normal nucleus-division in active cells occurs in many Algæ, Fungi, and Protophyta.

All cases of lobed and partially constricted nucleus are not, however, due to fragmentation; they sometimes result from a process of coalescence of nuclei. This occurs not unfrequently in the formation of endosperm, as in *Corydalis cava*, and in *Ephedra* at the period of maturity of the corpuscula and commencement of the development of the embryo.

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* Bot. Ztg., xxxviii. (1880) pp. 845–54 (pl. xii. figs. 1–22).

† See this Journal, iii. (1880) p. 979.

‡ *Ante*, p. 265.

Hypertrophy and Multiplication of Nuclei in the Hypertrophied Cells of Plants.*—M. E. Prillieux describes the multiplication of nuclei in the roots of plants which have germinated in a soil, the temperature of which generally exceeded by about 10° that of the surrounding air; two, three, or four nuclei have been found in each cell, and they were either isolated or united into a mass, and closely adpressed one to another; sometimes they were of the same size, but they frequently varied in size and form.

A number of nuclei in a cell have often been observed, but the phenomenon has generally been studied in the reproductive organs; in the cases observed by the author (in hypertrophied tissues) the nuclei have, to use the expression of Van Beneden, multiplied by *fragmentation.* These nuclei often contain a number of nucleoli, of various sizes and forms; the hypertrophied nuclei are vesicular, the protoplasmic mass is dense and finely granular, save in its centre, which is less dense and more liquid. The nucleoli are found in the parietal layer. When the nucleus divides, there is first formed in its interior a plasmatic partition; then the two halves swell and become isolated. This isolation is completed by the prolongation of the dividing fissure. In some cases the nuclei remain adpressed, and in this case the two new nuclei are formed in the interior of a portion of the protoplasm.

Histological Structure of Succulent Fruits.†—According to V. Borbás, the pericarp of succulent fruits consists sometimes of three, sometimes of four layers. The former is the case in the fruits of Solanaceæ, *Vitis vinifera*, *Ribes*, *Phytolacca*, *Hedera*, *Ligustrum*, *Berberis*, *Ophiopogon*, *Ruscus*, Cucurbitaceæ, and in the hesperidium of *Citrus;* while a fourth layer occurs in those of the Amygdaleæ (Drupaceæ), Caprifoliaceæ, *Cratægus*, *Rhamnus*, *Rivina*, and *Tilia.* The outermost layer, or exocarp, scarcely differs in structure from the epidermis of leaves. The thicker or thinner mesocarp is composed of parenchymatous cells. The endocarp resembles the exocarp in consisting of angular, or bulging, or occasionally of elongated cells. The fourth or sclerenchymatous layer is composed of lignified parenchymatous cells.

Anatomy of Adoxa Moschatellina.‡—M. P. van Tieghem calls attention to an interesting peculiarity in the internal structure of *Adoxa Moschatellina*, viz. a difference between the arrangement of the fibro-vascular bundles in the aerial stem and in the rhizome. In the former there are from four to six separate bundles arranged in a circle surrounding a large pith which is connected with the bark by medullary rays, but not enveloped by an endoderm. In the rhizome, on the contrary, the fibro-vascular bundles are all collected in the centre and surrounded by an endoderm; and there is no pith and no medullary rays.

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* Comptes Rendus, xcii. (1881) pp. 147–9.

† 'Földmivelési Erdekeink,' 1880. See Bot. Centralbl. i. (1880) p. 1299.

‡ Bull. Soc. Bot. France, xxvii. (1880) p. 282.

Vasa propria of Phalaris nodosa.*—G. A. Pasquale finds the subterranean buds of this grass from Sicily, 1–2 cm. long, to be enclosed in a fourfold sheath, destitute of chlorophyll, but filled with a bright red sap. The peculiar vessels filled with red sap are found also in the leaves, their number varying between sixteen and twenty-four, according to the breadth of the leaf. These vessels extend quite straight from the base to the apex of the leaf, and with no interruption to their cavity, except two or three oblique septa when the leaf is young. That they are not to be confounded with intercellular passages is shown by the independence of their walls, so that they can readily be isolated from the rest of the tissue.

The red fluid in the interior of these vessels is mucilaginous, slightly granular, thickens and coagulates in the air. The author is uncertain whether it is properly a pigment or latex. It is regarded by the Sicilians as poisonous.

Explosive Stamens.†—The sudden bursting of the anthers in the families Urticaceæ and Moreæ, by which the pollen is suddenly thrown out, has long been known. E. Askenasy has examined the structure of the organ concerned in *Parietaria erecta*, *Urtica dioica*, and *Pilea serpyllifolia.* In these species he finds the outer side of the filament covered with strong transverse ridges lying close to one another. The explosion has been supposed to depend on the sudden straightening of the previously strongly curved filament, from the removal of the pressure of the petals. But, according to Askenasy, this is not the case, at least in *Parietaria erecta*, where the cause is the development of the compressed, elastic, turgescent tissue of the filament itself.

Arrangement of Molecules in Trajectorial Curves caused by Growth.‡—Professor Schwendener discusses the growth of organized structures by intussusception in reference to the consequent necessary twofold arrangement of the molecules, viz. in layers parallel to the surface, and in rows at right angles, or nearly so, to that direction. On the surface, for example, of a young starch-grain, every small portion, as it grows to a greater distance from the organic centre, must take a definite course, the direction of which is shown by the fissures which result from drying up or from unequal swelling. From a mechanical point of view, all the forces which influence growth may be regarded as decomposed into two groups, a radial and a tangential. If the radial force alone were supposed to be in action in a mass of concentric layers, and the growth equally vigorous in the direction of all the radii, straight rows of molecules would be formed at right angles to the layers. But when the energy of growth has attained a maximum in the direction of any given radius, and then decreases on both sides, the radial rows pass into orthogonal trajectors, i. e. into lines which, traversing a system of curves, cut each of them at right angles.

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* Rendiconti R. Accad. Sc. Fis. e Matem. Naples, xix. (1880) p. 144. See Bot. Centralbl., ii. (1881) p. 76.

† Verhandl. naturw.-med. Ver. Heidelberg, ii. pp. 274–82 (1 pl.). See Bot. Centralbl., i. (1880) p. 1366.

‡ MB. k. Akad. Wiss. Berlin, 1880, pp. 408–32 (1 pl.).

But cases of section at right angles occur but rarely in nature, a great number of deviations being met with. One of the most frequent causes of these deviations is the circumstance that growth in the tangential direction, if it occurred by itself, would have a smaller intensity than growth in the radial direction. The consequence is that the originally orthogonal trajectors undergo a deviation towards the position of most active growth; this deviation increasing up to a maximum point, and then again diminishing, and being of course accompanied by a corresponding deviation from the rectangular section of the layers. A second cause of the deviation, which, however, can operate only in a cellular tissue, is the difference in pressure and turgidity between different zones or surfaces, the trajectors then deviating towards the side of smaller pressure, as is the case in wounds. The trajectorial curves may be segments of circles, ellipses, or parabolas.

Schwendener's explanation of some points connected with these phenomena differs from that of Sachs. The latter explains the direction of the medullary rays, as well as that of the anticlinal rows of cells in the apical region of stems and roots, on the same principle as that of growth by cell-division, that the new cell-walls are applied to those already in existence, thus causing rectangular section as a rule. Schwendener, on the other hand, considers cell-division as a special process of its own, while the formation of trajectorial rows, even in cellular tissue, is governed by the same mechanical principles that regulate the direction of the rows of molecules in starch-grains, thickened cell-walls, &c. The parallel course of the trajectors and of the cell-walls increases the effect, but is not the original cause.

Morphology and Physiology of the Leaf.*—K. Goebel treats in detail of the morphology of the leaf, especially, in the first place, in reference to the "cataphyllary" leaves (*Niederblätter* of Braun), which he regards as the result of true metamorphosis by degradation of the foliar leaves. Two forms of these leaves are especially discussed, the leaf bud-scales and the rhizome-scales. The former are especially characteristic of the deciduous woody plants of cold climates (occurring also in some evergreen Coniferæ), though they are not universally present; when absent, their function of protecting the growing bud against wet, drought, or cold is performed by a felt of hair, or some other special contrivance. The hairs in this case are almost invariably peltate. The transition from these scale-leaves to ordinary foliage-leaves is always sudden. In some cases the function of the bud-scales is performed by the stipules of the earliest leaves. Cataphyllary leaves occur in some Vascular Cryptogams, as in some species of *Isoetes*, *Struthiopteris*, and *Osmunda*, according to Prantl.

Secondly, the author treats of certain cases of habitual anisophylly, such as occurs in *Selaginella*, most foliose Jungermanniaceæ, and many flowering plants. This phenomenon is traced to special relationships of the plants in question towards light.

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* Bot. Ztg., xxxviii. (1880) pp. 753-60, 769-78, 785-95, 801-15, 817-26, 835-45 (1 pl.).

Absorptive and Diffusive Power of Leaves.[*]—The following are the chief conclusions on these subjects arrived at by P. Maquenne:—

1. All leaves disperse a portion of the heat they receive. If the Bourbouze light is used for this purpose, about 25 per cent. of the entire heat is dispersed; but with Leslie's cube only a small percentage.

2. The two sides of the leaves behave differently, the under side usually dispersing more light than the upper side; though sometimes the reverse was observed.

3. The leaves absorb a large portion of the heat of a Bourbouze lamp; this absorption depending on the water, chlorophyll, &c., contained in the leaves, and on diffusion at the surface of the cells. The upper side of the leaves absorb more heat than the under side.

4. Thick leaves are more absorbent than thin leaves.

5. The dark heat which radiates from boiling water is absorbed nearly as completely as by ordinary blackened surfaces.

6. Leaves allow the rays of heat to pass through them better the younger and thinner they are.

7. Leaves allow this heat to radiate almost as readily as lampblack.

8. The absorptive power of chlorophyll for dark rays of heat nearly equals that of water.

Colouring Matters of Flowers.[†]—Professor J. B. Schnetzler, in a paper on this subject, points out that hitherto it has generally been supposed that the various colours observed in plants were due to so many different matters, each colour being a different chemical combination without relation to the others. He is able, however, to show by experiment that when the colour of a flower has been isolated by putting it in alcohol, all the colours which plants exhibit may be obtained by adding an acid or an alkali. Plants of pæony, for example, yield, when macerated in alcohol, a violet-red liquid. If some acid oxalate of potash be added, the liquid becomes pure red; while soda changes it, according to the proportion used, into violet, blue, or green. In the latter case, the green liquid appears red by reflected light, just as a solution of chlorophyll does. The sepals of pæony, which are green bordered with red, become wholly red when placed in a solution of acid oxalate (binoxalate) of potassa. These changes of colour, which may be obtained at will, may well be produced in the plant by the same causes; since, in all plants, there always exist acid or alkaline matters. The transformation from green into red, observed in the leaves of many plants in autumn, is due to the action of the tannin which they contain, on the chlorophyll. Thus, without desiring to affirm it absolutely, Professor Schnetzler supposes, *a priori*, that there is in plants only one colouring matter, chlorophyll, which, being modified by certain agents, furnishes all the tints that flowers and leaves exhibit.

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[*] Maquenne, 'Recherches sur la détermination des pouvoirs absorbents et diffusifs des feuilles,' Paris, 1880. See Bot. Centralbl., ii. (1881) p. 70.

[†] Bull. Soc. Vaud. Sci. Nat., xvii. (1880) pp. 96–8. See 'Science,' i. (1880) p. 306.

Transformation of Albumen in Plants.[*]—According to E. Schulze, experiments made on seedlings have led to the following conclusion: that in the decomposition of albumen which accompanies germination, a mixture is always produced of various nitrogenous products of decomposition, and that these products are the same as those formed on heating nitrogenous substances with acids or alkalies. In seedlings of lupins were found, in addition to asparagin, a small quantity of leucin and traces of tyrosin, as well as some apparently new amido-acids, one of which, crystallizing in needles or plates, showed the composition $C_9H_{11}NO_2$.

A second result obtained was that the nitrogenous products of the decomposition of albumen formed in seedlings occur in totally different proportionate quantities to those obtained by the heating of albuminous substances with acids or alkalies. In seedlings of Leguminosæ asparagin, in those of Cucurbitaceæ glutamin is the most abundant albuminoid.

Chlorophyll which does not assimilate.[†]—Hanstein has observed in the central cells of *Chara* chlorophyll-bodies containing starch which could not be regarded as the product of assimilation. C. Dehnecke has now investigated a number of similar instances, in which the starch contained within the chlorophyll-grains appears not to serve the purpose of immediate assimilation, but to be stored up as a reserve material. This occurs, for example, in the cortical parenchyma of *Impatiens parviflora* and of many Polygonaceæ; in the young leaf-stalk of ferns, in the stem of the seedling of *Raphanus niger*, in the young sepals of *Tropæolum majus* and *Primula Auricula*, in the pericarp and flesh of the fruit, placenta, &c., of many plants, and in green potatoes. That there is no actual difference between those chlorophyll-grains which have and those which have not the function of assimilation is shown by the fact that in many cases the same grain will sometimes exercise successively the two functions of the storing up of starch and of assimilation. In certain cases the chlorophyll-grains of the kind under discussion were all found on the under side of the organ, and this was proved by experiment to be the result of gravitation.

Influence of the Intensity of Light on the Chlorophyll in the Assimilating Parenchyma.[‡]—Professor Stahl points out the importance, with regard to the reception of light, of the two different characteristic forms of cells ordinarily found in the parenchyma of flat leaves, the palisade-cells, with their longer diameter at right angles to the surface of the leaf, and the spongy parenchyma, the cells of which have their greatest extension parallel to the surface. In horizontal leaves the palisade-cells are found on the upper surface, the spongy parenchyma on the lower surface, while in vertical leaves

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[*] Landwirthsch. Jahrb. v. Thiel, ix. (1880) p. 689. See Bot. Centralbl., i. (1880) p. 1613.

[†] Dehnecke, C., 'Ueber nicht assimilirende Chlorophyllkörper,' Köln, 1880. See Bot. Ztg., xxxviii. (1880) p. 795.

[‡] Bot. Ztg., xxxviii. (1880) pp. 868–74.

and phyllodes the former are equally strongly developed on both sides of the leaf. The former therefore occupy the portion of the cell that is most, the latter that which is least exposed to the action of light; and this is connected with a difference in the distribution of the chlorophyll-grains in the two kinds of cell.

In the cells of the spongy parenchyma the chlorophyll-grains may occupy two positions. With a small amount of light they cover the cell-walls parallel to the surface of the leaf, or occupy a *superficial* position; more intense light causes them to assume the *profile* position on the walls at right angles to the surface. In the palisade-cells, on the contrary, whatever the intensity of the light, the chlorophyll-grains can occupy only one position, the profile.

The chlorophyll-grains in the palisade-cells receive the rays of light direct; those in the spongy parenchyma, on the other hand, receive those only which have been weakened by passing through the upper layers. This disadvantage is, however, to a certain extent compensated by the superficial position of the grains in the latter. The palisade-cells, with their cell-cavity elongated in a direction vertical to the surface, allow a considerable amount of light to pass through.

The thin leaves of plants which grow in deep shade, like *Oxalis acetosella*, *Mercurialis perennis*, and *Dentaria bulbifera*, have scarcely any palisade-tissue, while on the other hand, in the thick, stiff leaves of plants which are freely exposed to the sun, the spongy parenchyma is reduced to a minimum. Even the same species shows a difference in this respect according to the position in which it grows.

Heliotropism of the Ivy.*—The peculiar relations of ivy-cuttings to the light are well known, according to which they are negatively heliotropic when more strongly, positively heliotropic when less strongly illuminated. To determine the causes of its heliotropic phenomena, Dr. C. Kraus has experimented on three cultivated varieties. The ivy is peculiarly a shade-plant, and its growing shoots are therefore unusually sensitive to light. The difference between the upper and the under side of ivy shoots appears to be simply an excessive manifestation of the contrast so often manifested between the illuminated and the shaded side of branches; while the contrast, in those shoots where the phyllotaxis is biserial, between the sides which bear the leaves and those destitute of them, appears to be of a much more deep-seated and organic nature. The primary cause of the peculiar heliotropic behaviour of the ivy is stated by the author to be its specially great sensitiveness to light, in consequence of which internal changes take place in its shoots under strong light, the object of which is to obtain situations where the intensity of light is most favourable. The same conditions which relax and dwarf the leaves of the ivy in strong light, tend also to cause the stems to seek the most favourable intensity of light.

Pinguicula alpina an Insectivorous Plant.†—Dr. J. Klein has made an exhaustive examination of the anatomy and physiological

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* 'Flora,' lxiii. (1880) pp. 483–9, 499–514, 525–8 (1 pl.).

† Cohn's Beitr. Biol. Pflanzen, iii. (1880) pp. 163–85.

phenomena of this plant, which he finds to agree in every important point with those of *P. vulgaris.* The glands are of two kinds, stalked and sessile. The stalked glands consist of a basal cell projecting above the epidermis, a 1–4-celled stalk, and a hemispherical columella, to which is attached the glandular structure, in the form of a cap, and consisting of a layer of cells arranged radially. The sessile glands have a similar structure, but want the stalk; the columella is conical, and the gland does not project above the epidermis by more than one-half. They occur also on the under side of the leaf, but are there not so fully developed.

Asparagin.*—According to M. Meunier, if asparagin is heated with strong potash-ley, a portion of the nitrogen is eliminated as ammonia; and the quantity of asparagin can be determined by the estimation of this ammonia. By this method the author claims to have confirmed some previous statements with regard to the physiological purpose of asparagin. The quantity formed on germination varies with the duration of the germination, and with the nature of the seed. In the first period of germination, the same quantity of asparagin is formed in the light and in the dark; subsequently it accumulates in etiolated plants, and disappears in those exposed to light.

Diseases of Plants.†—Professor B. Frank has published the first portion of a very useful and complete handbook on the diseases to which plants are subject; those caused by fungi being treated with especial detail, and with regard to all the newest observations.

B. CRYPTOGAMIA.

Classification of Thallophytes.‡—Professor De Bary reviews the classifications of Thallophytes proposed by Cohn, Sachs, Winter, Eichler and others, and suggests a new scheme differing somewhat from them all. Sachs's system, depending on the one character alone of the sexual organs, he considers too precise and artificial, like that of Linnæus for flowering plants; while Cohn's primary division into two groups only will not bear examination. De Bary's proposed classification is into eight primary groups, viz.:—

1. *Chlorophyceæ* (corresponding nearly to Thuret's group of that name); including all chlorophyll-green thallophytes with polysymmetrical zoospores, and reproduced also by zygospores or oospores; including *Hydrodictyon, Ulothrix, Botrydium, Acetabularia, Œdogonium, Coleochæte,* &c. The structure of the thallus is extremely variable, and the sexual reproduction is either *isogamous*, by the conjugation of similar gametes, or *oogamous*, by the fecundation of an oosphere by antherozoids. Between these two modes there is every stage of transition; nearly allied forms, like *Eudorina* and *Pandorina*, sometimes differing in this respect. The highest position among the

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* 'Annales agronomiques,' vi. (1880) p. 275. See Bot. Centralbl., i. (1880) p. 1461.

† Frank, Dr. B., 'Die Krankheiten der Pflanzen.' 1te Hälfte. Breslau, 1880. See also *infra*, p. 282.

‡ Bot. Ztg., xxix. (1881) pp. 1–17 and 34–6.

Chlorophyceæ is undoubtedly occupied by forms, like the Œdogonieæ and Coleochæteæ, in which the reproduction is definitely oogamous. Two families of green algæ present special difficulties in their localizing under this arrangement, viz. *Vaucheria*, which, while having itself highly differentiated sexual organs, is nevertheless nearly allied, by its monosiphonous thallus, with the isogamous Siphoneæ; and the Conjugatæ.

2. *Phæophyceæ*; corresponding nearly to Harvey's Melanospermeæ, and including the Fucaceæ, Cutleriaceæ, and Thuret's Phæosporeæ and Tilopterideæ. This group has its lowest forms in the isogamous Phæosporeæ, and its highest in the oogamous Fucaceæ.

3. *Rhodophyceæ*, comprising the Florideæ, Porphyreæ, Bangieæ, and the marine Chantransieæ, a well-defined group, with the Dictyoteæ as a doubtful member.

4. *Cryptophyceæ* (of Thuret); i. e. the Nostocaceæ in the widest sense of the term, including the Chroococcaceæ and the Schizomycetes.

5. *Diatomaceæ.*

6. *Characeæ.*

7. *Fungi*; comprising all the organisms generally understood by this term except the Schizomycetes and Myxomycetes, but including the Lichens.

8. *Myxomycetes.*

If we turn our attention especially to the four largest of these classes, the Chlorophyceæ, Phæophyceæ, Rhodophyceæ, and Fungi, we shall see that each constitutes a series complete in itself, ascending from very lowly to higher forms, and that none of them dovetail into one another; although the lowest forms might in some cases be classed indifferently in one or the other series. Thus *Pythium* and the simplest Phycomyceæ, constituting the lowest member of the Fungi, are closely allied to the Chlorophyceæ. The series of Chlorophyceæ is connected upwards from the Œdogonieæ and Coleochæteæ, through the Bryophyta, with Vascular Cryptogams and flowering plants. The other three series do not lead up to higher forms.

The simplest Phæophyceæ, as *Ectocarpus*, are separated from the Chlorophyceæ by the structure of the zoospores, the formation of phycoxanthin, &c., although exhibiting a distinct affinity with certain chlorosporous forms, as *Stigeoclonium*, *Chroolepus*, and *Cladophora*. The simplest Rhodophyceæ, as *Bangia*, *Chantransia*, and *Nemalion*, are already endowed with highly differentiated sexual organs, and show most analogy to *Cutleria* and perhaps *Tilopteris* among the Phæophyceæ, and to *Coleochæte* among the Chlorophyceæ. The Fungi, which find their highest development in the Ascomycetes and Uredineæ, show the closest relationship to the Œdogonieæ among the Chlorophyceæ, *Monoblepharis* finding a place equally well in this family or in the Phycomycetes; and *Pythium* being also almost equally well placed in the Chlorophyceæ; while *Mycoidea parasitica* appears to be a chlorophyll-green, zoospore-forming *Peronospora*.

The anomalous Characeæ present the appearance of being the terminal member of a series of which the lower stages have been lost;

their assumed analogy with the Dasycladeæ having been disproved by the recent discovery of the mode of reproduction of the latter.* In some respects they exhibit most relationship to the Vaucherieæ.

The Diatomaceæ are undoubtedly most nearly allied to the Conjugatæ, but their true position must for the present remain doubtful.

The Cryptophyceæ or Schizosporeæ, to which the Schizomycetes are undoubtedly closely allied, form a well-defined group, characterized by their structure, the formation of spores and hormogonia, and the presence of phycochrome.

In an accompanying comparative table, the author arranges the Chlorophyceæ in four parallel columns, one of which leads to the Bryophyta, Pteridophyta, Gymnospermia, and Angiospermia; while the Phæophyceæ, Rhodophyceæ, and Fungi occupy one column each springing at different stages from the Chlorophyceæ; and the whole originating from the Cyanophyceæ and Schizomycetes. The whole vegetable kingdom can be again arranged in ascending series in six stages, viz. 1. Agamæ (or Cyanophyceæ); 2. Isogamæ; 3. Oogamæ; 4. Carposporeæ (these three stages including the remainder of the Thallophytes); 5. the Archegoniatæ (divided into Isosporæ or Bryophyta, Filices, and Lycopodiaceæ, and Heterosporæ comprising Rhizocarpeæ and Ligulatæ); and 6. Anthophyta or Gymnospermæ and Angiospermæ.

Cryptogamia Vascularia.

Development of Sterile Sporangia in Isoetes lacustris.†—Of the three methods by which the sterility of these sporanges is caused, E. Mer states that (1) *arrest of development* takes place by the cessation of the growth of the sporange, even before the formation of trabeculæ; the cells of the formative tissue remain unaltered, and exhibit no starch. Growth may cease after the trabeculæ and hypodermal layer are formed; the formative tissue-cells have multiplied and become enlarged, but all growth ceases before they become separated. Finally, the spores may even be formed, only to shrivel up. Reduction of temperature is the cause of arrested growth, which has been observed chiefly in the variety *sporifera*. *Invasion of the formative by the nutritive tissue* is another method (2), which is chiefly noticed in the forms *sporifera* and *gemmifera*, and appears to be caused by cold, as in the former case. Its essence consists in the great development assumed by the hypodermal layer and the trabeculæ; a quantity of starch accumulates in these parts. The external part and some detached portions in the interior are all that is left of the formative tissue, or else it is only the lower part of the sporange which degenerates into amyliferous tissue, the upper part, which is constricted off from it, forming the spores, which may sometimes ripen. Thirdly (3), the sporange is sometimes observed to be *converted, after its formation, into amyliferous tissue.* It then preserves its shape, but remains very small; or it may develop small protuberances on its surface. These may advance to the condition of leaves,

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* See this Journal, *ante*, p. 96.

† Comptes Rendus, xcii. (1881) pp. 310-12.

receiving fibro-vascular bundles from the parent leaf; these leaves form buds, which either become detached or adhere to the plant, often growing very vigorously and forming secondary and tertiary shoots. The young leaves may grow out at the base, from inability to find space at their apices; the sporanges there formed degenerate into amyliferous tissue. Further, the lower part of the sporange may become a leafy bulbil, while the upper part produces spores; this case is most common in the macrosporangia of vigorous and isolated plants. In very rare cases, these bulbils themselves bear leaves containing fertile sporanges. The sporange may be reduced to a small amyliferous mass, lying between the epidermis and the fibro-vascular bundle of the leaf, thus demonstrating what is its true morphological origin; this is not apparent from the normally developed sporange, which is already further advanced when it is first observed. Lastly, some leaves (e. g. var. *sterilis*) exhibit no trace of a sporange.

Muscineæ.

Shoots from the Pedicels of the Inflorescence of Marchantia.[*]—J. Klein has observed, on certain inflorescences of *Marchantia polymorpha* which lie prostrate on the soil, but are still in connection with the thallus, smaller or larger shoots springing from the pedicel, and resembling the normal thallus. These shoots occur on both the female and male inflorescences, but most frequently on the latter, since the locality of these on the thallus is nearer to the soil. Each pedicel usually produces only one, and always at its upper end, near to the peltate receptacle, this being the part that comes first into contact with the damp soil. Each shoot produces on its lower side a more or less dense felt of rhizoids, which may remain exposed in the air or may penetrate the soil. The largest that was observed measured 14 by 8 mm.

These shoots appear to be always formed in the so-called "radical channels,"[†] and may, perhaps, be regarded as dormant bulbils; since, in addition to those which develop into shoots, there are always a number of similar but very minute rudimentary bodies concealed by the lateral lobes of the channels; these are distinguished from the rest of the pedicel by their bright green colour. They were found also in the upper parts of the pedicels of erect female inflorescences that had not come nearly into contact with the soil.

Klein considers that these observations confirm the accepted theory that the inflorescences of *Marchantia* are transformed axes of the thallus.

Geocalyceæ.[‡]—C. M. Gottsche publishes the result of some recent observations on the structure of this interesting family of Jungermannieæ.

Firstly he identifies with *Calypogeia ericetorum* Raddi, two Hepaticæ

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[*] Bot. Centralbl., ii. (1881) p. 26.

[†] See this Journal, iii. (1880) p. 991.

[‡] Abhandl. Ges. Naturw. Hamburg, vii. (1880) pp. 39–66. See Bot. Zeit., xxxviii. (1880) p. 746.

gathered respectively by Nyman in Sicily, and by Philibert at Bona in Algeria.

In the typical forms of *Calypogeia*, e. g. *C. Trichomanis*, as also in *Geocalyx* and *Saccogyna*, the archegonia are seated on a short branch which is subsequently widened at its extremity into the "fertile sac" (*Fruchtsack*) beneath the surface of the soil, within which the sporogonium is formed, subsequently emerging from it laterally by the side of the stem. In *C. ericetorum*, on the contrary, the archegonia are seated on the upper side of the stem, between the two rows of leaves (there being no amphigastria), six or seven together. After fertilization, they bend downwards; the under side of the stem puts out a protuberance which elongates into a long cylindrical "fertile tube" (*Fruchtrohr*), as much as 5 mm. in length, and closed at the lower end. This tube strikes vertically downwards into the soil, and is clothed with small rhizoids. The sporogonium is subsequently formed at the base of this tube, the mouth of which stands open among the involucral leaves, and not by the side of the leaves, as in *Geocalyx*, *Saccogyna*, and *Calypogeia Trichomanis*. The Sicilian plant is the only European Hepatica in which this singular structure has been observed.

The author also gives full diagnoses of the genera *Gongylanthus* and *Podanthe*, and of some new or little-known species.

A new German Sphagnum.[*]—E. Hampe gives the following diagnosis of a new species of *Sphagnum*, on which he bestows the name *S. subbicolor*, found on the margin of a ditch at Helmstedt, growing in detached cushions, submerged when the water is at a high level, and resembling in habit elongated and lax forms of *S. cymbifolium*.

Dense cæspitosum, pulvinatim explanatum, mollissimum, pallide flavescens, siccum hyaline albescens; vivum capite viridi ornatum. Caulis robustus, erectus, usque spithameus, simplex vel divisus; ramis interioribus caulem tegentibus deflexis, exterioribus alternis patenti-recurvatis deflexis attenuatis apicibus filescentibus. Folia caulina flaccida, ampla, e basi angustiore obovato-rotundata, cucullato-concava, immarginata, integerrima; cellulis basilaribus internis crassioribus inanibus, cellulis tenuioribus dimorphis, usque ad basim folii circumdatis, cellulis apicalibus crassioribus subquadratis. Folia ramorum laxe imbricata, sicca apicibus recurvis, ovato-lanceolata obtusa, apice cucullato-contracta concava, cellulis dorsalibus incrassatis, cristatis, omnibus dimorphis. Folia comalia viridula, dense imbricata breviora, ovata, obtusa, concava. Fructus deest.[†]

Fungi.

Carbon- and Nitrogen-compounds as Sources of Nutriment for the lower Fungi.[‡]—Prof. Naegeli has carried out a long series of experiments for the purpose of determining from what compounds of

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[*] 'Flora,' lxiii. (1880) pp. 440–1.

[†] Dr. Braithwaite considers this to be identical with *S. papillosum* Lindberg.

[‡] SB. Akad. Wiss. München, 1880, pp. 277–367.

carbon and nitrogen the lower fungi most readily derive those elements. The general results may be stated as follows:—

As respects nitrogen, all those compounds may be regarded as favourable which are comprised under the general terms amides and amines, whether the oxygen is also consumed or not. While acetamide, methylamine, ethylamine, propylamine, asparagin, and leucin supply both carbon and nitrogen, the latter only is absorbed from oxamide and urea. All ammoniacal salts are also available to fungi as sources of nitrogen, while some also make use of nitrates. Free nitrogen is useless, nor can it be absorbed out of cyanogen or of any compounds in which it is present only in the form of cyanogen. When this is apparently the case, it results from ammonia having been first formed.

As a general statement respecting the nutritive power of nitrogen-compounds, it may be said that nitrogen is most easily assimilated when present as NH_2, less so when in the form of NH, and still less so as NO, while it cannot be assimilated at all if combined with any other element than H or O. From such compounds the oxidizing action of fungi may, however, produce a substance of the group NO, which is subsequently reduced to one of the NH_2 series.

Carbon can be absorbed from a great variety of organic compounds; with access of oxygen almost all carbon compounds are nutritive, whether acid, alkaline, or neutral, provided they are soluble in water and not too poisonous. Amongst the few that are not useful in this way are CO_2, cyanogen, urea, formic acid, oxalic acid, and oxamide. The assimilable carbon-compounds contain the element in the form of CH_2 or CH; and it is probable that the latter group are available only when two or more atoms of C with which H is combined are also directly in combination with one another. For example, methylamine (with 1 C and 3 H) and benzoic acid (with a chain of C atoms, each with 1 H) are nutritive, while formic acid (with only 1 C and 1 H), and methyl-alcohol, are not. Carbon cannot be assimilated when directly in combination, not with H, but with some other element, as in the cyanogen group, urea, oxalic acid, and oxamide, where only atoms of N, O, and C are in direct combination with the C.

Irrespectively of the chemical constitution of the nutrient substance, the living cell will, under similar circumstances, most readily absorb those substances which are the most readily detached from their compounds, and therefore require the least force. Prof. Naegeli has drawn up the following list of the most frequent sources of nitrogen and carbon, advancing from those which are most favourable to those that are least so:—1, Albumen (peptone) and sugar; 2, leucin and sugar; 3, ammonium tartrate or sal-ammoniac and sugar; 4, albumen (peptone); 5, leucin; 6, ammonium tartrate, ammonium succinate, asparagin; 7, ammonium acetate.

Pathogenous Fungi in the Animal Organism.[*] — In previous publications Dr. P. Grawitz has shown the remarkable similarity, in

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[*] Arch. Path. Anat. Physiol. (Virchow), lxxxii. (1880) pp. 355–76.

all essential points, of the dermatophytes which accompany different infectious diseases, as well as their apparent identity with the milk-ferment, *Oidium lactis.* He had also given reasons, derived from a number of careful experiments, for believing that these fungi were not true parasites, but partook more of the nature of saprophytes. More recent experiments by Grohe and Block appeared to lead to an opposite conclusion; and Dr. Grawitz is not able to offer an explanation of these apparently contradictory results.

The two most widely distributed and best known of the fungi in question, *Aspergillus glaucus* and *Penicillium glaucum*, each occur in two different forms which present no morphological difference, but which differ very widely in their physiological properties. The one (saprophytic) may be introduced into the blood of the higher animals without showing any disposition to germinate; the other (parasitic) germinates and spreads with the greatest facility, and is eminently pathogenous. Both forms may be produced from the same original stem, and each form may be reproduced through from twelve to twenty generations, and may then give birth to the other. The malignity of the pathogenous form depends on the entrance of the spores into the blood, where they germinate, and then pass with great rapidity into the various tissues of the body, where they cause local necrosis.

Spore-diffusion in the larger Elvellacei.*—Mr. C. B. Plowright describes the result of some observations on about 100 specimens of *Morchella gigas* Pers. In the evening, as the rays of the setting sun fell obliquely upon them, he observed that all the older specimens were quietly and continuously diffusing their sporidia. Each sporidium was distinctly visible to the naked eye, floating in the air, twisting and turning in the sunlight. The head of each of the morells was surrounded by a cloud of sporidia extending 3 or 4 inches above and around it. This cloud could only be seen in the oblique light against a dark background. When acted upon by a gentle current of air, such as would be produced by gently waving the hand, it swayed to and fro without manifesting any tendency to become dispersed. The component sporidia were in constant motion, rising and falling, and circling about, as if there was no law of gravity. When the cloud was blown quite away by a more powerful air-current, it in the course of a few seconds re-formed. The contents of each ascus could be seen to be separately ejected in a minute jet, consisting of a limited number of sporidia, which speedily became lost with the others forming the cloud.

The phenomenon is, he considers, interesting from a physiological point of view, as showing the capabilities of the unaided human eye. These sporidia measured only about one-hundredth of an inch in their long diameter, and five one-thousandths of an inch in their short, yet they could distinctly be seen to be bodies having length and breadth.

What particularly struck him when observing these spores being

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* 'Grevillea,' ix. (1880) pp. 47–8.

given off, was the facility with which they floated in the air, having little or no tendency to subside. Their specific gravity must be very low, and this, aided by their gyrations, will account for the extensive and, when aided by air-currents, rapid diffusion of Elvellaceous sporidia.

Formation and Germination of the Spores of Urocystis.*—E. Prillieux has succeeded in following out the mode of germination and the process of formation of the spores in two species of *Urocystis*, *U. Violæ* and *Colchici*.

In all the species of *Urocystis* the spores are associated into ovoid or roundish masses, the outside portion of which is formed of cells which must be regarded as imperfect and sterile spores, while a small number of fertile spores occupy the centre of the mass; those are dark brown and nearly opaque, while the outer ones are transparent, and but slightly coloured. In *U. Violæ* the number of fertile spores in each mass varies from two to eight, while occasionally there is only one; in *U. Colchici* there are usually only one or two. In both species the mass of spores is surrounded by a close tissue of filaments, in the midst of which the masses may be observed in various stages of development. These filaments penetrate the interior of the cells of the host, while those of the vegetative mycelium develop exclusively in the intercellular spaces. They are the final ramifications of the mycelium, and are well termed the sporogenous filaments. From its origin the glomerulus or mass of spores is seen to be composed of interwoven sporogenous filaments, forming a little ball which recalls the structure of some sclerotia. As this glomerulus increases in size, certain of its central cells become distinguished by their greater size, and assume the character of true spores, while the adjacent ones develop into the superficial sterile spores, and the rest of the sporogenous filament becomes mucilaginous, and finally disappears. The fertile spores are in fact formed from the extremities of the sporogenous filaments in the same way as in *Tilletia* rather than in *Ustilago*.

The germination of the spores of *Urocystis Violæ* takes place in the following way. Three or four days after having been sown on water, the spore gives birth to a promycelium which may be longer or shorter, unicellular or multicellular. At its extremity the promycelium produces a crown of six sporidia. Each glomerulus usually produces only one promycelium, though occasionally there are two or three. The sporidia are at first short and somewhat curved like a finger; ultimately they elongate, all the protoplasm of the promycelium passing into them. They germinate while attached to the apex of the promycelium. Each produces at its extremity a secondary sporidium, twice as long as but narrower than the primary sporidium. The protoplasm finally passes from the primary into the secondary sporidia, which then detach themselves and float on the surface of the fluid. The process of germination therefore differs from that previously described by Kühn and Wolf in the case of *U. occulta*.

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* Ann. Sci. Nat., x. (1880) pp. 49–61; and Bull. Soc. Bot. France, xxvii. (1880) pp. 204–8.

New Entomophthora-forms.*—Dr. G. Winter describes two very interesting recently discovered forms of species of *Entomophthora.*

The basidiospores of *Entomophthora aphidis* were found in aphides on the leaves of *Cornus sanguinea*, the individuals attacked by the parasite being distinguished by their bright brown colour and swollen abdomen. The author gives the following diagnosis:—Sporiferous hyphæ much coiled, sparsely septated, colourless, somewhat club-shaped above, 12 μ in diameter, springing from isolated, asciform, colourless cells, about 9 μ in diameter; spores elliptical, fusiform, often unilateral, less often somewhat curved, usually with a small apiculus, colourless, 26–30 μ long, 10–15 μ broad. On the same leaf were found also individuals containing resting-spores of the parasite.

The second discovery is the long-sought resting-spores of *Entomophthora muscæ*, which were found in flies whose death takes place in moist places. Among eight or ten such individuals, the author found several containing the ordinary basidiospore-form of the fungus, while three contained a mycelium of a precisely similar character, with numerous resting-spores; one individual produced both forms. The mycelium has the form of short, thick, curved or coiled hyphæ, often producing one or two branch-like protuberances, with swellings at the end or some other part, and containing much oil. The spores appear as roundish lateral or terminal swellings; when ripe they are usually perfectly spherical, colourless, with a uniformly thick cell-wall, and are also rich in oil; occasionally they are somewhat pear-shaped. Their diameter varies between 30 and 50 μ.

Sclerotia from Peziza.†—Specimens of a *Helianthus* of which the roots contained abundance of a white cottony mycelium were examined by M. Cornu, and found to contain a sclerotium (*Sclerotium varium*), which, on germinating, gave birth to *Peziza sclerotiorum.* The rhizomes of *Anemone nemorosa* were also found by the same observer infested and completely destroyed by a sclerotium belonging to *Peziza tuberosa.*

Fungus-parasites of Coniferæ.‡—Von Thümen supplies a monograph of all the known forms belonging to the so-called genus *Peridermium*, which includes the æcidio-forms of *Chrysomyxa Rhododendri*, *Coleosporium Senecionis*, and *Calyptospora Goeppertiana.* There are at present sixteen species and two varieties known, growing on twenty-three hosts, twenty-two of which belong to the Abietineæ, and one to the Gnetaceæ, none being known on the Taxineæ or Cupressineæ.

Urocystis coralloides.§—E. Rostrup has observed the roots of *Turritis glabra*, even to the capillary branches at a distance of several inches from the main root, to be covered with a quantity of very

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* Bot. Centralbl., ii. (1881) p. 62.

† Bull. Soc. Bot. France, xxvii. (1880) pp. 209–10.

‡ Mittheil. forstl. Ver. Oesterreich's, ii. (1880). See Bot. Centralbl., ii. (1881) p. 131.

§ Bot. Centralbl., ii. (1881) p. 126.

irregular, coral-like, leaden-grey bodies of all sizes up to a diameter of 4 cm. They were filled with a dark brown conglomerate of spores which were first formed in the root permeated by hyphæ, but afterwards increased so greatly in number that the root was burst open, and the mass of spores exposed, which then either enveloped the finer roots with a weft, or else formed the coral-like bodies which appeared like appendages to the roots, and were buried in the soil. The mass of spores was surrounded by a thin weft of colourless hyphæ, and was composed in the centre of from one to three large dark brown spores, with a diameter of 12–16 μ, surrounded by a number of smaller spores; the nearly or quite round mass having a diameter of 30–40 μ. The fungus belongs, undoubtedly, to the genus *Urocystis*, but is characterized by its subterranean habit and large size.

The same writer also records the discovery of red masses of long multicellular teleutospores in leaves of *Pyrola minor*, belonging to *Uredo Pyrolæ.* The structure of the teleutospores shows the fungus to belong to the Coleosporei, and to be closely related to *Coleosporium Ledi.* The correct name is therefore *Chrysomyxa Pyrolæ.* The author believes it to be connected genetically with *Æcidium conorum Piceæ* found in proximity on cones of *Picea excelsa.*

Species of Hysterium parasitic on Cruciferæ.[*]—K. Prantl has investigated the development of *Hysterium nervisequium, macrosporum,* and *pinastri* on the leaves of various Cruciferæ. He finds that after the germinating hyphæ have perforated the epidermis, weeks, months, or even years may elapse before any signs of disease are visible on the leaves. The fructification takes from two to seven years to mature. According to the nature of the host, the disease may be either chronic, when the leaves do not lose their colour for a considerable time, and remain on the plant until the parasite is mature; or acute, when the leaves at once both lose their colour and drop from the tree.

Chestnut-disease.[†]—G. Gibelli describes in detail the disease which extensively attacks chestnut-trees in Italy and the South of France. Abandoning his previous theory that it is the result of depauperation of the soil, the author now hesitates between attributing the disease to fine mycelial overgrowths of the apices of the roots, or to pycnidia detected by him on the diseased roots.

Plant-diseases caused by Fungi.[‡]—R. Hartig publishes an exhaustive account of the various diseases caused in trees, cultivated crops, and other plants, by the attacks of fungi. He discusses several difficult questions which arise in connection with the subject, as for example the apparent hypertrophy of the tissue of the host, without any evil consequences resulting from the attacks of some of these parasites.

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[*] Forstwissensch. Centralbl., 1880, pp. 509–13. See Bot. Centralbl., i. (1880) p. 1261.

[†] Gibelli, G., 'La malattia del Castagno,' Modena, 1880.

[‡] Hartig, R., 'Ueber die durch Pilze bedingten Pflanzenkrankheiten,' München, 1880. See also *supra*, p. 273.

Germ-theory applied to Fungi parasitic on Plants.[*]—M. Cornu considers that M. Pasteur's theory may be applied with advantage to the explanation and treatment of parasitic diseases of plants. He calls attention to the fact that the parasitic fungi of Europe do not generally infest the whole plant, but only certain organs which may be cast off; and that when the fungus is thus cast off with these parts it is for a considerable time at the mercy of the weather; further, it will produce reproductive germs which again, pending their development into a new plant, are delivered over to the risks of surrounding conditions. Perpetuation of the species is effected—1. By persistence of the mycelium, as such, through the winter, to reproduce the species in the spring, as is the case with some *Ascomycetes*. 2. By production, at the death of the mycelium, of germs fitted to withstand unfavourable conditions, and attacking the plants at the most suitable times, as happens with the *Uredineæ*, *Ustilagineæ*, *Peronosporeæ*, *Chytridineæ*, *Myxomycetes*, and some *Ascomycetes*.

These organisms may be thus combatted:—1. By placing the cast-off parts of their hosts under such conditions as to destroy the parasites. This may be effected by drying the leaves, branches, &c. (for the *Phacidiæ*, *Dothideaceæ*, most *Septoriaceæ*, &c.), or by using the leaves as food or litter for cattle, or for compost, or (as with *Peronosporeæ*, &c.) by more violent means. For example, those parts of the vine which are affected by *Oidium* or by anthracnose should be removed, and the twigs of that year's growth should be washed with compounds of sulphur, such as the sulpho-carbonates; this method destroys at the same time the winter eggs of the *Phylloxera* and *Pyralis*. When *Peronospora viticola* is present, the leaves and detached twigs should be burned; the ashes may be used as manure.

Composition of the Protoplasm of Æthalium septicum.[†]—J. Reinke enumerates a long list of substances as immediate constituents of the naked protoplasm of the fructification of *Æthalium septicum*. The plastin forms a swollen plastic continuous framework in the interior of the plasmodia, as well as the firmer pellicle on their surface, and can be separated by pressure from the fluid portions of the protoplasm. The albuminoids amount to scarcely 30 per cent. of the dry substance. This appears to dispose of the theory that protoplasm consists merely of albumen. From a chemical point of view the protoplasm even of the lowest organisms is a highly complicated structure. Among the non-organic constituents of the protoplasm under investigation are ammonium carbonate, calcium carbonate, phosphate, and sulphate, magnesium (probably phosphate), potassium phosphate, sodium chloride, and iron; there were also found calcium stearate, palmitate, oleate, lactate, oxalate, acetate, and formiate, as well as a large number of organic substances.

Intrusion of a Fungus into the Pulmonary Tissue during Peripneumonia.[‡]—While withholding his judgment as to the cause of

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[*] Comptes Rendus, xci. (1880) p. 960.

[†] Reinke, J., "Ueber die Zusammensetzung des Protoplasma von *Æthalium septicum*." See Bot. Ztg., xxxviii. (1880) p. 815.

[‡] Comptes Rendus, xcii. (1881) pp. 254–6.

this disease, whether it is due to a microscopic fungus or not, M. Poincaré calls attention to the appearances observed in the lungs of some cows which died of this disease. He found the bronchial and pulmonary cavities loaded with a mixture composed of epithelial cells and nuclei, of particles of hay, straw, and starch-grains. The lung tissue itself contained a fungoid mycelium which penetrated in all directions, and might be observed to grow, especially in fresh pulmonary tissue. The fibres are flattened, branched, without septa, and contain irregularly scattered vacuoles; they vary in diameter from 0·0084 to 0·0035 mm. The fructification, which may be studied by keeping the fresh tissue for two or three days under a watch-glass at blood-heat, then giving out a strong odour of mildew, forms immense numbers of spores resembling animal cells in appearance. Whether this fungus is or is not to be considered as the cause of the disease can only be determined by experimental inoculation and examination of other diseased subjects.

Influence of Antiseptics on Mucor.*—M. B. Wenkiewicz cultivated *Mucor* in a nutrient fluid (Bucholtz's modification of Pasteur's) consisting of 10 grammes candy-sugar, 1 gr. ammonium tartrate, and ½ gr. potassium phosphate, in 100 c.c. water; and then experimented on the retarding effects on the resulting *Mucor*-growth of various antiseptics in the following manner. The freshly prepared and clearly filtered fluid was poured, while still hot, into flasks of 20 c.c. capacity. Measured quantities of the antiseptic of known concentration were then added by means of a pipette in which hundredths of a cubic centimetre could be easily read off. The fluid was then freely shaken up, and about three drops of the *Mucor*-culture added, and the flask closed by a carbolized wad. The flasks were then laid aside for twenty-one days at a temperature of 20°–30° C. A list is given of the relative quantities of the various substances required to neutralize the *Mucor*-growth, the most powerful being corrosive sublimate, iodine, and chlorine.

Two New Mucorini.†—M. Bainier describes and figures two new species of Mucorini. *Rhizopus reflexus* was observed on leaves of *Arum maculatum*, but can be readily cultivated on boiled bread. It is characterized by the recurved sporangiferous filaments. The stem is from 2 to 2·5 mm. in height, while the spores measure from 0·0084 to 0·0105 mm. *Helicostylum piriforme*, like the rest of the genus, possesses sporangia of two kinds; the spores contained in them being, however, of the same size, about 0·021 mm. The smaller sporangia are pear-shaped.

New Coloured Bacterium.‡—C. Bergonzini records the discovery of a new coloured bacterium on a solution of white of egg which had been evaporated to less than half its volume, and had lost its white

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* Wenkiewicz, B., 'Das Verhalten des Schimmelgenus *Mucor* zu Antisepticis u. einigen verwandten Stoffen,' Dorpat, 1880.

† Bull. Soc. Bot. France, xxvii. (1880) pp. 226–8 (1 pl.).

‡ Ann. Soc. Nat. Modena, xiv. (1880) pp. 149–58. See Bot. Centralbl., i. (1880) p. 1528.

opalescent for a yellowish colour passing readily into green, with a dark violet pellicle. The colour could not be due to the accidental presence of aniline-pigment. A closer examination showed also that the colouring-matter of the pellicle was not readily soluble in water, and hence could not be due to *Chromococcus violaceus*; and that it was composed of innumerable rod-bacteria which appeared motionless when collected into masses, but distinctly displayed motion when swimming about freely in the fluid. These violet bacteria bore a great resemblance in their form and dimensions to *Bacterium Termo;* they were cylindrical, about 0·6–1·0 μ thick, and 2–3 μ long, being from two to three times as long as broad. When observed singly, the colour appeared scarcely blue, while when massed together the violet tint was very perceptible. The pigment was insoluble in water, slowly soluble in ether, very rapidly in alcohol. Addition of water to the alcoholic solution produced no precipitate, leaving the fluid clear.

The author was able in most cases to infect fresh prepared solution of white of egg with bacteria from the pellicle. At a temperature of 17°–19° C. the first traces were visible after about eight days, a few violet dots making their appearance on the surface of the fluid. The following is the diagnosis of the new species.

Chromobacterium violaceum. The cylindrical cells are isolated, two to three times as long as broad, are possessed of an oscillatory motion, and are coloured violet by a pigment insoluble in water. The thickness varies from 0·6 to 1 μ, the length between 2 and 3 μ. They vegetate on a solution of white of egg.

Cultivation of the Bacterium of Foot-Rot.[*]—The course of this disease is stated by M. Toussaint to occupy at least thirty-five days, but it may be recognized in sheep affected with it during the incubation-period, which may last more than twenty days. The lymph taken from pustules formed by inoculation may be utilized to form a growth of the parasite; this growth can be propagated in broth of different kinds of meat—best in that of rabbit or mutton broth—and even in yeast-solution. In this case the growth develops strongly in from two to three days, filling the liquid with bacteria and spores, and forming pellicles on the surface; in from four to five days the liquid becomes clear, as the bacteria then sink to the bottom in the form of spores. In the first stage the bacteria commence at a length of 0·003 to 0·004 mm. and are then very active; they elongate and become segmented; usually but two joints are found in union, of which one is generally larger than the other; at the third or fourth day the longer joint produces a spore at each end, and sometimes one in the middle; the small joint forms one spore which, having a greater diameter (viz. 0·001 mm.) than that of the joint, gives it a club-shaped outline. The spores are oval, and refract the light, and are smaller than those of anthrax. Inoculation of sheep from these liquids produces pustules which reach their greatest size in from fifteen to eighteen days; they never suppurate, but disappear without any general accompanying eruption, and they leave no

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[*] Comptes Rendus, xcii. (1881) pp. 362–4.

scar. The temperature rises by from $\frac{1}{2}$° to 1° by the fifteenth day. It remains to be seen whether inoculation from artificial growths, such as now described, is able to produce immunity from this complaint.

Influence of Concussion on the Growth of Bacteria.[*]—J. Reinke has carried out a carefully devised series of experiments, for the purpose of confirming (or otherwise) the old statement that bacteria will not develop at all in a fluid which is in constant active motion. The result was that, while the development was greatly hindered, it was not found to be actually prevented. The author suggests the possibility of a connection between the hindering effect of concussion on the development of bacteria, and the well-known but inexplicable hindering effect of light on vegetable growth.

Long Life of Anthrax Germs: their Preservation in Cultivated Soils.[†]—Further experiments relating to the conditions under which anthrax germs occur in soil have been undertaken by Messrs. Pasteur, Chamberland, and Roux. Soil from two burying-grounds—one in use for the last three years, the other not used since twelve years previously—proved to be infectious, and imparted anthrax to fowls inoculated from it. Of seven sheep which were confined for some hours at midday during several fine days over the older burying-ground, not being allowed to feed there, one died of anthrax on the sixteenth day, and a second on the thirty-first day after the commencement of the experiment; none of the remaining five sheep, or of the rest of the flock, died during this period. The seven sheep had never had the disease previously; they must have obtained the germs when sniffing over the ground, according to the habit of sheep.

Vegetables had been grown on the same ground, and one case (not fatal) of malignant pustule had appeared among the human beings inhabiting the farm in question. Thus cultivation of plants, with their assimilating and combustive powers, is not sufficient to destroy all the organic matters of manure and night-soil, for these germs survive it, and very slight alterations in the mode of life of the animals inhabiting such a place might entail an outbreak among them which might be communicated to man by the bites of flies, &c.

New Disease due to the Action of the Saliva of a Child who died from Hydrophobia.[‡]—M. Pasteur (aided by MM. Chamberland and Roux) describes the results of the inoculation of certain animals with the saliva of a hydrophobic child. Four hours after death, a little of the mucus of the mouth was dissolved in water, and immediately two rabbits were inoculated with it. These died after thirty-six hours. Fresh rabbits were then inoculated, either with the saliva or with the blood of the first rabbits; these died more rapidly.

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[*] Pflüger's Arch. f. Physiol., xxiii. p. 434. See Naturforscher, xiv. (1881) p. 56.

[†] Comptes Rendus, xcii. (1881) pp. 209–11.

[‡] Ibid., xciv. (1881) pp. 159–61.

Inoculation of fresh blood produced death in about twenty-four hours.

On autopsy, the first thing that was noticed was that the veins of the abdomen, in which region inoculation was practised, were much more noticeable than ordinarily. Many of the ganglia were swollen and hæmorrhagic. There was emphysema of the cellular tissue. The lungs gave indications of pulmonary apoplexia, and the trachea was almost always congested. The blood was more or less liquid, and coagulated feebly. The appetite of the inoculated rabbits was bad, and these symptoms began to be marked five or six hours after inoculation. Later on there was a manifest tendency to paralysis. Shortly before death there appeared to be a great flow of saliva.

The blood of the animals thus treated was found, on examination, to contain a remarkable microscopic organism, of an exceedingly small size. It had the shape of a small rod, a little constricted in the middle, so as to give a figure of 8 appearance, and the diameter of each half was often not more than $0 \cdot 5\ \mu$ in diameter. (Since the rods have been cultivated they have increased in size, and are now nearly twice their original size.) M. Pasteur has convinced himself, by a series of cultivation-experiments, that this minute organism is the real cause of the disease; while in blood it has the form already described, it has in the cultivation fluid the form of more or less long chaplets, made up of a variable number of joints, all of which have the figure of 8 form, but which are somewhat larger than those seen in the blood. The guinea-pig exhibits a great resistance to the action of this morbific organism.

M. Pasteur hopes that, if hydrophobia can be shown to be due to the presence of a microscopic organism, it may not be beyond the power of science to find some means of diminishing the action of the virus, so as not only to preserve to man his dogs, but to save him from the effects of a disease which is never contracted save from their caresses or their bites.

Nature of Malaria.[*]—The most recent discoveries in this subject are summed up by Tommasi-Crudeli thus:—The cause of the malady was determined by Klebs and himself in 1879 to be a distinct species of *Bacillus*, which was found in the atmosphere and soil of all infected districts; if introduced into the systems of animals, it produced an intermittent fever and the lesions characteristic of this disease. It is found developing in affected animals, especially in the spleen and medulla of the bones, the parts which are most altered in human patients.

Marchiafava has found the same species of bacillus in human subjects which have died of the disease, in the lymphatic glands and in the blood of all the veins, in addition to the parts above mentioned; but subsequent research did not show its presence in the arteries. The same observer has now established that certain stages of the disease correspond to certain states of development of the parasite; in the feverish stage the organism occurs in the blood only under the

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[*] Atti R. Accad. Lincei, Transunti, iv. (1881) pp. 19-21.

form of free spores; in the *cold* stage, the blood always contains bacilli, mostly in the stage described as *sporogenous* by Tommasi-Crudeli, some, however, as filaments with barren joints or with sporogenous joints. It is found in the blood of all parts of the body.

Tommasi-Crudeli has endeavoured,* by experiments, to discover a means of rendering man proof against malaria. He has found that arsenic, which can be used in the case of some other fevers, often more advantageously than quinine, is an important agent in this case. Thus a regular application of Fowler's arsenical fluid to men living throughout the summer in some of the most malarious parts of the Campagna, has restored their appetite and vigour, and has for two seasons preserved them from the disease. Experiments on dogs, made by Marchiafava and Cuboni, have shown that the disease may be imparted by means of the blood of a diseased animal. Two points remain to be determined: (1) the possibility or not of ensuring a cure by the use of arsenic; (2) the minimum dose which will suffice to effect this object. The general advantages of this medicine are shown by the fact that, in the epidemic of malaria which lately visited the town of Caserta, gelatine tablets containing arsenic were found very useful; they afford a means of regulating the proportions of doses very minutely.

Animal Nature of Myxomycetes.—Mr. W. S. Kent has recently† supported the view of the purely animal nature of Myxomycetes, which he considers to be established beyond question, classing them with the sponges. "In both the formation of the gigantic compound plasmodium, and in the development therefrom of the characteristic sporangia, these Myxomycetes exhibit certain phenomena singularly suggestive of a more or less remote affinity with the sponges. In these latter also the initial term takes the form of spore-developed uniflagellate monads, which uniting in social colonies, form a gelatinous mass, corresponding closely with the plasmodial element of the former group. In the fine horny network, usually contained with the spores within the sporangium developed by the mature plasmodium, a substance is produced singularly resembling the fine horn-like elements or keratose fibre of certain sponges, while, what is still more remarkable, in certain forms, spicule-like bodies, composed of carbonate of lime, are also developed within the substance of the walls of the sporangium, or so-called 'peridium,' that accord substantially in outline with the stellate siliceous spicula of the Tethyidæ and other familiar sponge-groups."‡

Dr. Cooke§ strongly opposes this view, and considers that the animal nature of the Myxomycetes "rests on similar and no better evidence than the animal nature of the zoospores so common in algæ, or the animal nature of diatoms."

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* Loc. cit., pp. 22–4.

† Kent, W. S., 'A Manual of the Infusoria.' (8vo. London, 1880.)

‡ Loc. cit., p. 43.

§ 'Grevillea,' ix. (1880) pp. 41–3.

Algæ.

Cell-nucleus in Algæ.[*]—Schmitz supplements his previous observations on the presence of one or more nuclei in the cells of Thallophytes[†] by the following, relating chiefly to the Florideæ.

In *Batrachospermum*, *Chantransia*, *Liagora*, *Dudresnaya*, *Corallina*, *Jania*, *Melobesia*, *Hapalidium*, *Cruoria*, *Cruoriopsis*, *Peyssonelia*, *Petrocelis*, &c., he found invariably only small cells with one nucleus each. The Corallineæ often manifest a coalescence of two cells of the tissue by resorption of the partition-wall. In *Jania rubens* the mass of the protoplasm has coalesced, the nuclei remaining distinct. In *Spondylothamnion multifidum*, *Ceramium rubrum*, *gracillimum*, *fastigiatum*, *strictum*, and other species of the genus, besides the small cells, the large cells of the stem have also only one nucleus.

In most other species of Florideæ the larger cells are multinucleated; for example, *Spyridia filamentosa.* In a large number of species the smaller cells have only one, the larger several nuclei.

Many species of *Griffithsia* and *Bornetia*, *Monospora pedicellata*, *Spermothamnion flabellatum*, &c., have also several small nuclei in the younger cells. The species of *Callithamnion* exhibit a great diversity; in some species the youngest cells are uninucleated, in others, like the older ones, multinucleated.

The reproductive cells show great uniformity in contrast to the vegetative cells. The tetrasporangia are always uninucleated, and this is also the case with the spermatia (antherozoids) and the carpogenous cells of the procarpium. The nuclei of the sexual are always larger than those of the vegetative cells.

The multiplication of the nucleus in the multinucleated cells is always effected by bipartition, and is independent of the division of the cell itself.

Of the remaining marine algæ, the Bangiaceæ, Dictyotaceæ, and Phæosporeæ have always uninucleated cells. Among Ulotrichaceæ, the marine species *Urospora mirabilis* is multinucleated.

The presence of several nuclei was observed in some fresh-water algæ, as *Hydrodictyon utriculatum* and *Botrydium granulatum.* In the Protococcaceæ and allied forms only a single nucleus could be detected in each cell.

Formation of Endogenous Shoots in Algæ.[‡]—In confirmation of the statement of Falkenberg[§] of the occurrence of an endogenous formation of normal branches in *Rhytiphlœa*, *Vidalia*, and *Amansia*, H. Ambronn has reobserved the phenomenon in the two last-named genera, to which he adds also *Polyzonia.*

Vidalia spiralis, *Amansia multifida*, and *Polyzonia elegans* and *incisa* exhibit precisely the same phenomena as the species described

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[*] SB. niederrhein. Ges. Natur. u. Heilkunde, Bonn, 1880. See Bot. Centralbl., i. (1880) p. 1281.

[†] See this Journal, ii. (1879) p. 606; iii. (1880) pp. 111, 303, 482, 493; i. (1881) p. 69.

[‡] SB. Bot. Ver. Brandenburg, 1880, pp. 74–6.

[§] See this Journal, iii. (1880) p. 138.

by Falkenberg; but the two first-named species produce also adventitious shoots of exogenous origin on the mid-rib of the thallus. The facts are, therefore, precisely the opposite to those that occur in the higher cormophytes, where the normal shoots have an exogenous, the adventitious shoots an endogenous origin. A third species, *Polyzonia jungermannioides*, which bears a remarkable resemblance in habit to some species of *Jungermannia*, presents a somewhat different structure.

Spiral Phyllotaxis in Florideæ.*—Professor Schwendener has investigated the regular spiral phyllotaxis of the lateral organs in *Polysiphonia*, *Spyridia*, and other Florideæ, for the purpose of determining whether it depends or not on the contact of the organ with the next oldest one.

In those species of *Polysiphonia* with the lateral organs in four rows, viz. *P. sertularioides*, *variegata*, &c., the breadth of the rudiments of the youngest leaves at the apex is about one-fourth of the circumference of the stem; which supports the theory of contact. The young leaves are closely applied to the stem by their inner surface, and the apices of the uppermost leaves invariably reach to the level of those freshly formed.

In *Polysiphonia Brodiaei*, the leaves (lateral organs) are arranged in a $\frac{1}{7}$ phyllotaxis, and the relationship of the breadth of the rudiments to the circumference of the stem is in correspondence. The phenomena are the same in *P. sertularioides*; and in *Chondriopsis* it is $\frac{2}{7}$. In *Spyridia filamentosa* the arrangement is $\frac{5}{13}$, and the structure the same as in many flowering plants. As the segment-cells are very short, and each produces a leaf-rudiment, their hooked projections are closely adpressed. These facts render it scarcely doubtful that the occurrence of a spiral arrangement of the lateral organs depends on the same causes as in higher plants. The same is the case in *Acanthophora*.

Sargassum and the Sargasso Sea.† — Dr. O. Kuntze gives the following as the general results of a very careful examination of the various points connected with the so-called "gulf-weed," *Sargassum bacciferum*.

1. The diagnosis of the species by Linnæus, Turner, and C. and J. Agardh depends on a series of errors, and presents no constant character by which it can be distinguished from *S. vulgare*.

2. Very different forms have been described by later authors and travellers as *S. bacciferum*, the reputed species being found only in the floating state, and belonging to the most extreme species of the genus.

3. The floating specimens consist entirely of broken-off upper branches, which are mostly much branched, with numerous small bladders, while the lower parts, which are less branched, have a few large bladders, and, when old, are leafless, and entirely wanting in the open sea.

4. It is only the remains of old plants that are found floating,

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* MB. k. Preuss. Akad. Wiss., 1880, pp. 327–38.

† Engler's Bot. Jahrbuch, i. (1880) pp. 191–239. See also 'Nature,' xxiii. (1880) p. 70.

while the young plants, which in *Sargassum* are unbranched, without bladders, and densely covered with leaves, would not be wanting if *S. bacciferum* were a floating pelagic species.

5. The floating fragments are always in a state of etiolation or decay; the olive-green colour in reflected light has almost entirely disappeared.

6. The position of the tufts of branchlets is usually reversed, the apices pointing downwards, and the broken ends of the stems upwards.

7. There is no regular growth in the floating *Sargassum;* even the abnormal growth which the fragments often display in the water for a short time, is hypothetical, and has not been accurately observed.

The plant is variable in almost every single characteristic; and about 300 different forms have been described as distinct species; a synopsis is given of the more important.

The author has come to the conclusion that the ordinary statements of a "Sargasso Sea," with a definite and constant area, are not founded on fact. The floating fragments occur throughout the Atlantic Ocean, and the prevailing winds and currents cause them to accumulate sometimes in one part, sometimes in another.

A fresh classification is appended of all the genera of Fucaceæ, the primary division being as follows:—A. Sporanthia (i. e. the pits with the organs of reproduction) dispersed over the thallus. B. Sporanthia upon the bladders. C. Sporanthia on special terminal inflorescences. A new genus, *Xiphophyllanthus*, is founded on *Blossevillea xiphocarpa* Harv.

With regard to *Macrocystis pyrifera*, the author doubts the correctness of the statements as to its enormous size, it being stated that the fronds attain a length of 1000 feet.

Spermothamnion torulosum.[*]—F. Ardissone has examined perfect specimens of this seaweed, which has been assigned to both *Griffithsia* and *Callithamnion*, and considers it to be a true *Spermothamnion.* The cystocarps must not be confounded with the true favellæ of *Callithamnion*, but present the form of a terminal bunch of spores provided with a common periderm, and surrounded by an involucre composed of branchlets. The spherospores are developed here and there on the branches. They are rounded, and sessile or pedunculate, and with a nucleus divided in three. The antheridia are developed on special branches, are conical in form, and are borne on a large basal cell.

Genetic Connection of certain Unicellular Phycochromaceæ.[†]—In connection with his researches on *Glœocystis*,[‡] P. Richter suggests whether various forms of unicellular algæ hitherto considered distinct, and ranged under the genera *Glœocapsa*, *Chroococcus*, *Aphanocapsa*, *Glœothece*, and *Aphanothece*, are not really genetically connected, displaying a kind of polymorphism; a form with but slightly encysted cells (*Aphanocapsa*) intervening between one with encysted spherical

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[*] Atti Soc. Critt. Ital., xxiv. (1881) p. 24.

[†] 'Hedwigia,' xix. (1880) pp. 169–71 and 191–6.

[‡] See this Journal, *ante*, p. 98.

(*Glœocapsa*) and one with encysted cylindrical cells (*Glœothece* and *Aphanothece*). A similar relationship has, in fact, already been suggested by Naegeli in his 'Einzelligen Algen.'

The form previously described by the author under the name *Aphanothece caldariorum* presents an intermediate form between that genus and *Glœothece,* and would appear to be completed in its cycle of development with two other forms named by A. Braun *Glœothece inconspicua* and *Aphanocapsa nebulosa,* being a maturer condition of the first of these two. In the same way, A. Braun's *Aphanocapsa biformis* may be shown to occur in three different forms.

The lowest form of the Phycochromaceæ is the naked *Aphanocapsa* condition, corresponding to *Palmella* among the Chlorophyllophyceæ. From this naked or only slightly encysted condition is developed the *Glœocapsa* or *Glœocystis* form with several gelatinous envelopes; the *Chroococcus* type, when the investment is altogether wanting; or, when there is only a single vesicular envelope, the cœnobium types. The *Glœocapsa* type is specially adapted for exposure to the air and growth upon a comparatively dry substratum; the cœnobium type is developed in water; the *Chroococcus* type in water or on a moist substratum in the air. With this is connected the cylindrical form, a higher stage, because it displays a differentiation in the direction of growth, and a development towards the filiform condition. This is not always developed, and may be distinguished into stable and unstable forms. The latter may occur in two or three varieties, and may go through the following successive conditions:—

1. Stable *Aphanocapsa* and *Palmella.*
2. *Aphanocapsa* and *Palmella* which have attained to *Glœocapsa, Glœocystis,* or cœnobium type, but which always revert to the naked solitary spherical form.
3. Stable *Glœocapsa, Glœocystis, Chroococcus,* and cœnobium forms without reversion (*Merismopedia*).
4. Cylindrical forms, the generations of which pass through the solitary spherical (*Aphanocapsa* and *Palmella*) condition, as well as the *Glœocapsa* and similar forms.
5. Cylindrical forms which pass through only the *Glœocapsa* and similar forms.
6. Cylindrical forms, the generations of which revert to the *Aphanocapsa* and *Palmella* condition, while the *Glœocapsa* or any similar form is suppressed.
7. Stable cylindrical forms (*Synecococcus*).

No reference is made in the above to the passage of *Glœocapsa* into the encysted filiform conditions of *Sirosiphon,* corresponding to *Palmodactylon* and *Hæmospora* among the Chlorophyllophyceæ.

Crystalloids of Marine Algæ.* — J. Klein enumerates fifteen Florideæ in which crystalloids have at present been found; as also one species of each of the genera *Acetabularia, Bryopsis, Codium, Dasycladus,* and *Cladophora.* The most remarkable are those of *Dasycladus,* which are large, brown, and distinctly striated.

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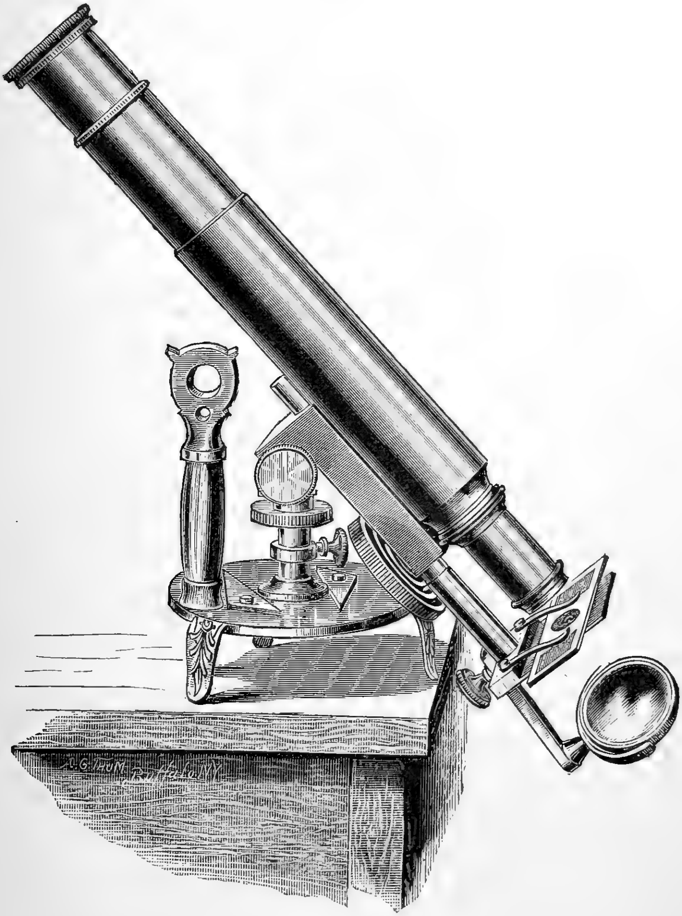
* Klein, J., "Neuere Daten üb. die Krystalloide der Meeres-algen." See Bot. Ztg., xxxviii. (1880) p. 782.

MICROSCOPY.

a. Instruments, Accessories, &c.

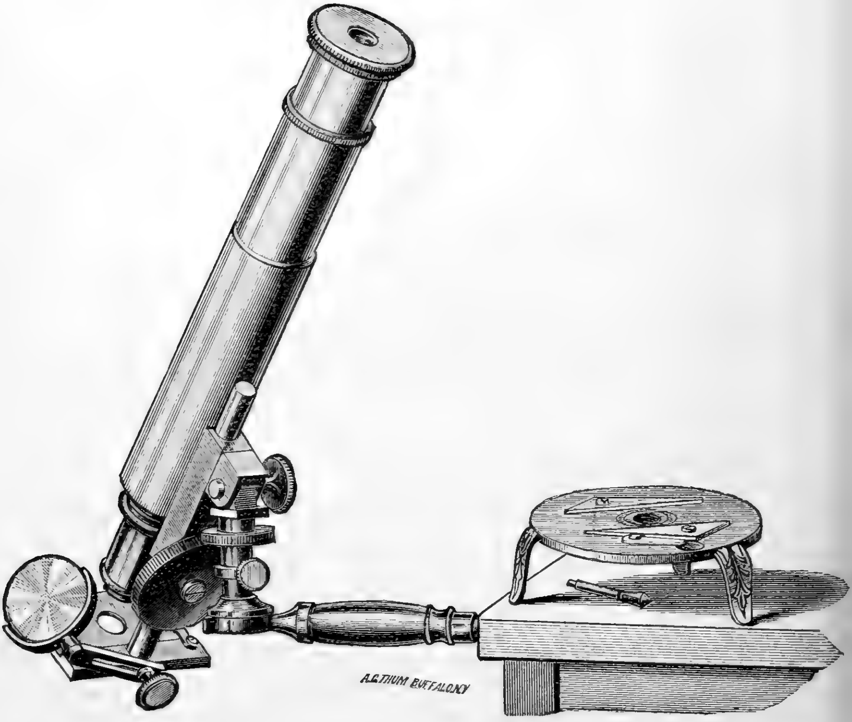
Griffith Club Microscope.—Figs. 39, 40, and 41, show a new form of portable Microscope designed by Mr. E. H. Griffith, of Fairport, N.Y., U.S.A., and designated by him the "Griffith Club Microscope." Mr. Griffith claims for the new instrument certain merits in regard to compactness and portability, which distinguish it specially for class or field work.

Fig. 39.



The stand proper can be attached to a metal disk provided with three feet; it then appears as in Fig. 39. The bottom of the box is also provided with a metal fitting into which the standard carrying the Microscope can be screwed, which we regard as the most convenient way of using the instrument. An extra screw-arm (shown lying in front of the box in Fig. 41) is also provided, which can be screwed to the end of a laboratory table, as shown in Fig. 40. The metal disk forming the foot in Fig. 39 also serves as an ordinary self-centering turntable, as shown in Fig. 41.

Fig. 40.



The coarse adjustment is effected by a sliding cylindrical rod attached to the back of the microscope-body. The fine adjustment consists of a large milled head attached to the lower end of the bar in which the coarse adjustment rod slides, the inner face having a deep spiral groove of nearly three turns, in which works a pin projecting behind the cylindrical tube carrying the stage; the rotation of the spiral causes the pin and tube, together with the stage, to move somewhat slowly in a vertical direction within a range of half an inch —sufficiently well for the use of low powers. (Fig. 39 shows the pin in the second ring of the spiral.)

The mirror has the usual gimbal motions, and is attached to a sliding bar at the back of the stage, swinging laterally and approximately concentric with the object upon the stage. (Fig. 40 shows the mirror swung above the stage.)

The draw-tube has the "Society" screw at the lower end, and a

FIG. 41.

fitting is provided to permit the inclination of the stand to any desired position.

The feet of the turntable can be removed for convenience of packing. The whole of the metal work is nickelized.

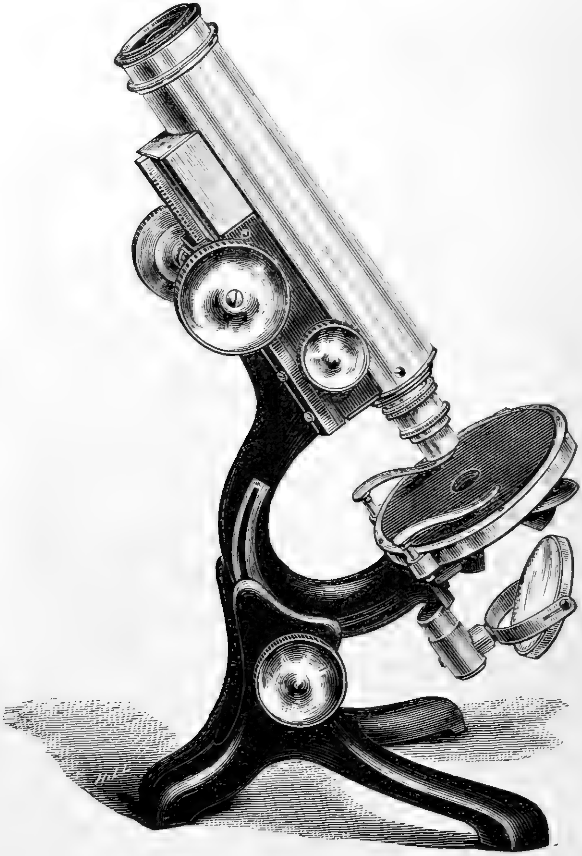
The box (shown about half-size in Fig. 41) is intended to carry the stand, eye-piece, two objectives, turntable, sundry bottles, &c., and the lid is glazed with strong plate glass. We understand that

Mr. Griffith proposes to apply an extra carrier for a small candle or other illumination for class work.

The new Microscope appears to be the result of much ingenious planning on the part of its author to produce what he terms a "*multum in parvo*" instrument.

Swift's Student's Microscope (Wale's Model).—It will be seen from Fig. 42 that the main feature in Wale's Microscope*—the inclination of the main limb by the motion in sector between vertical jaws—has been applied by Messrs. Swift in their new stand. Their calotte diaphragm is also added (shown in part beneath the stage).

Fig. 42.



The principal novelty is the fine adjustment (Fig. 43, nearly full

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[*] This Journal, iii. (1880) p. 1046.

size). A is a brass plate having short angle-bearings at either end sliding in the grooves B B and carrying at the lower end a ring into which the objectives are screwed. A spiral spring C presses down the plate A. The focussing is by means of the fine screw worked by the milled head F, the point of which acts upon the trigger-shaped lever D (attached to the side), which pushes against the small metal disk E (mounted on A and rotating on a pinion to diminish friction) and this lifts up the slide A against the pressure of the spiral spring above. The ring carrying the objective is quite independent of the microscope-body, and should the slide A be found to work too easily or the reverse, the bearings can be readily adjusted by the capstan screw-heads shown at the side.

Fig. 43.

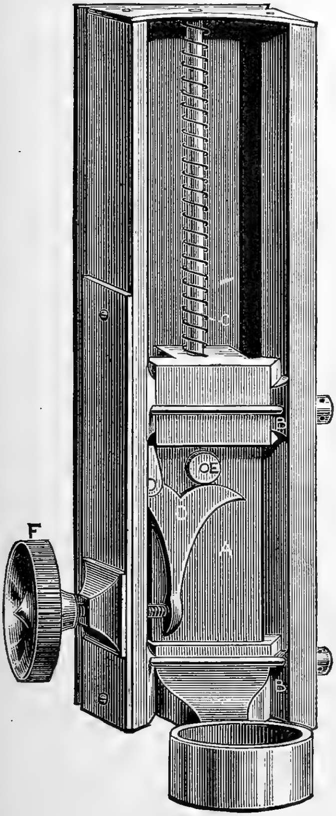
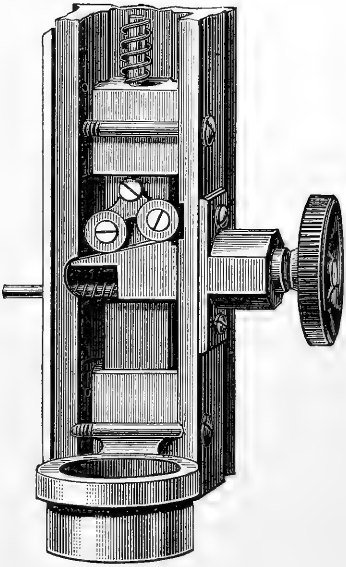


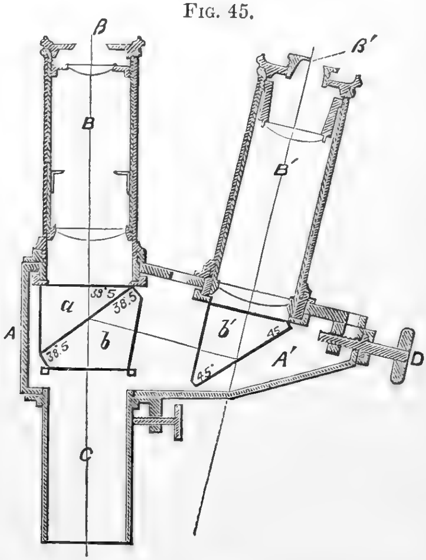
Fig. 44.



An improved application of this fine adjustment has since been devised, as shown in Fig. 44; the modification consisting of a wedge-shaped lever worked by the fine-focussing screw (against a short spiral spring) and acting on the slide A by means of the two small revolving disks attached loosely by a triangular fitting to the pinion at E. By making the slope of the wedge very acute, and the thread of the screw very fine, the focussing movement is rendered unusually delicate. This latter form of fine adjustment is designed to be applied to more expensive Microscopes.

Abbe's Stereoscopic Eye-piece.*—Fig. 45 represents this instrument in section. The body A A′ contains three prisms of crown glass, *a*, *b*, and *b*′. The two eye-pieces B B′ are let into the top plate, the former being fixed, whilst the latter has a lateral sliding movement; the bottom plate carries the tube C for inserting the eye-piece into the microscope-tube like an ordinary eye-piece.

Fig. 45.



The two prisms *a* and *b* are united so as to form a thick plate with parallel sides, their continuity, however, being broken by an exceedingly thin stratum of air—less than 0·01 mm.—inclined to the axis at an angle of 38·5°. The cone of rays from the objective is divided into two parts, one being transmitted and the other reflected. The transmitted rays pass through *a*, *b* without deviation, and form an image of the object in the axial eye-piece B. The rays reflected at the angle shown in the figure pass through the second surface of the prism *b* (upon which they are incident at right angles), and emerging at an inclination of 13° with the horizontal, are totally reflected into the eye-piece B′ at an angle of 90° by the hypothenuse surface of the right-angled equilateral prism *b*′, the axis of which also makes an angle of 13° with the axis of the Microscope.

* Zeitschr. f. Mikr., ii. (1880).

Adjustment for different distances between the eyes is effected by the screw D, which moves the eye-piece B′, together with the prism b', in a parallel direction. The tubes of the eye-pieces can also be drawn out, if greater separation is required.

The eye-pieces have the usual two lenses, but are of special construction in order to equalize the length of the direct axis and the doubly reflected axis, and in spite of this inequality obtain sharply defined images of equal amplification with the same focus.

Stereoscopic vision is obtained by *halving the cones of rays above the eye-pieces.* This is effected by stopping off half of the real image of the objective opening formed above the eye-pieces at the so-called "eye-point" β or β', which represents the common cross-section of all the pencils emerging from the eye-piece. A cap, with a semicircular diaphragm, is fitted to the eye-piece (shown in the figure over B′), the straight edge of which is exactly in the optic axis of the eye-piece, and can be raised or lowered by screwing so as to obtain a uniform bisection of the cones of rays from every point of the field.

The height of the diaphragm is regulated once for all for the same length of the microscope-tube by finding the position for which the aperture-image (which on withdrawing the eye from the eye-piece is visible as a bright circle above it) shows no parallax against the straight edge of the diaphragm, i. e. so that on moving the eye laterally the image always appears to adhere to the edge.

In addition to the above caps with diaphragms, the instrument is supplied with ordinary caps with circular apertures, as in B. They taper slightly, and simply slide into the eye-piece, so that they can be readily changed.

The special feature of the instrument is the ingenious arrangement whereby, by simply turning the caps with the diaphragms, orthoscopic or pseudoscopic effect can be produced instantaneously at pleasure. It is more particularly available for tubes of short length for which the Wenham prism is inapplicable.

Some discussion subsequently took place as to this instrument,* in the course of which it was pointed out that the device for dividing the rays was similar to that suggested by Mr. Wenham in 1866,† the method of its application, however, and the action of the binocular as a whole being essentially distinct and in fact truly stereoscopic, and not *non*-stereoscopic as supposed.

A further point raised was ‡ that a *crossing* of the axes in such an arrangement was essential, in regard to which, however, Prof. Abbe properly points out—what has hitherto not been appreciated—that stereoscopic or pseudoscopic effect does *not* depend essentially on crossed or not-crossed axes, but upon either the outer or inner halves of the pupils of the observer's eyes being put into action in binocular vision. As the author has dealt fully with this point in the paper read at the January meeting,§ we need not refer further to it here.

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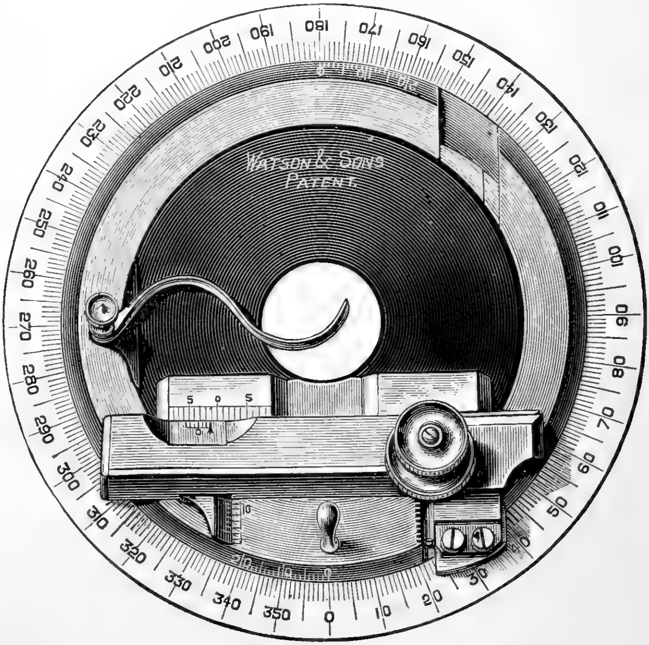
* Engl. Mech., xxxii. (1880) p. 323.
† Quart. Journ. Micr. Sci., xiv. (1866) p. 104.
‡ Engl. Mech., xxxii. (1880) p. 352.
§ See this Journal, *ante*, p. 203.

Watson's Mechanical and Rotating Stage.—Fig. 46 shows an improved form of stage by Mr. Watson, with the mechanical movements applied to and wholly controlled on the surface and within the circumference. It will be remembered that at pp. 117–18 we figured and described Tolles's mechanical stage, embodying similar movements. In the Watson stage, however, the lower plate or bar, travelling vertically, is sunk below the surface of the stage and moves in a dovetailed groove ploughed out of the rotating plate, and carries a pinion whose teeth gear into a rack cut into or attached to one side of this groove. By turning the milled head fixed to this pinion—the upper one in the figure—the plate carrying it moves in a vertical direction. To this bar is attached another at right angles, with a similar groove ploughed out, in which works a second plate having teeth cut upon its lower edge gearing into those of a second (hollow) pinion placed on the first, and, by means of a tube fitting the axis of the latter, turning independently upon it by the lower milled head shown. Thus, as with the ordinary "Tyrrell" pinion movement, by turning either of the milled heads separately, rectangular motion can be obtained—or, by turning them both together, diagonal motion.

Fig. 46.



To the plate or bar, traversing horizontally, is attached the top plate (upon which the object slide is placed), the thickness of which is about the fiftieth of an inch. The pinions are made to work on the same axis for convenience of being controlled by one hand.

The top plate has an improved spring arrangement (largely adopted in America), for securing the slide; upon unscrewing the milled head on the left hand, the spring may either be turned aside or removed altogether, when the stage will be free to carry a trough or other large object.

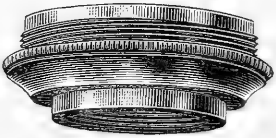
The usual graduated "finders" are added, but instead of the ordinary pointers, verniers, reading to $\frac{1}{100}$ of an inch, are applied.

The circular stage rotates within a broad fixed ring. This ring is preferably made of phosphor-bronze, and is graduated round the whole circle, and the readings are taken by verniers. For petrological or other purposes requiring exact angular measurements, the verniers will be found of service. In the stage figured the range of the rectangular motions has been limited to an inch in either direction, but when requisite this can be largely increased.

The total thickness of the stage is only about $\frac{1}{4}$ inch. Actual use is necessary to determine whether the endeavour to get extreme thinness has or has not been carried too far so as to give liability to flexure.

"Butterfield" Gauge of Screw for Objectives.—Frequent references have recently been made in the American journals to a gauge of screw for objectives of much larger diameter than that of the "Society" screw. It is known as the "Butterfield" gauge, and is shown in Fig. 47 (actual size) in the form of an adapter to screw directly into the microscope-tube; the opening beneath is of the usual "Society" gauge. The purpose of the new gauge is to permit the extension of the apertures of low powers by the utilization of much larger diameters of back lenses than can be utilized with the smaller gauge—the latter would, in fact, act as a diaphragm to the new objectives, cutting off a portion of the effective aperture.

Fig. 47.



Homogeneous-immersion Objective with extra Front Lenses.—Messrs. Powell and Lealand have completed a $\frac{1}{12}$ having two extra front lenses on the plan noted in vol. iii. p. 1050. The maximum numerical aperture is 1·43 (= 140° in crown glass of mean index 1·525), obtained by a front lens several degrees greater than a hemisphere, mounted on a plate of glass ·003 inch in thickness, which is itself mounted in the usual metal-work by the zone projecting beyond the circumference of the lens.

With this front lens the focal distance from the exposed face of the plate on which the lens is mounted is ·007 inch.

A second front, nearly a hemisphere, is mounted in the usual way by a burred edge of metal covering the extreme margin of the lens. This front gives a numerical aperture of 1·28 (= 115° in glass), and the focal distance is then ·016 inch.

The third front provides a numerical aperture of 1·0 (= 82° in glass, as nearly as possible), and the working distance is then ·024 inch —probably the greatest working distance hitherto obtained with a $\frac{1}{12}$ of that aperture, a result of course due to the homogeneous-immersion formula.

The new objective thus affords an important practical demonstration of the accuracy of the views enunciated by Professor G. G. Stokes, in his paper in vol. i. pp. 140-1, that if a front lens, aplanatic *per se*, were constructed of very large aperture, by reducing the thickness of the lens zones of the aperture would also be cut off, and the distance gained between the spherical refracting surface and the focus would be available for "working" distance. The three fronts exemplify this exactly, for they are all made from the same substance of glass and the curvatures have the same radius, the interchange of fronts simply changes the aperture and the working distance, the magnifying power being the same with each (allowance made for the impossibility of mounting the fronts, so that the vertices of the curved surfaces should be *exactly* at the same plane—that is, at the *same* distance from the posterior combinations). The utilized diameter of the posterior lens (with the front of highest aperture) is the largest that has been hitherto utilized for a $\frac{1}{12}$; the second front utilizes a less diameter, and the third still less,—the ratios being that the front of lowest aperture utilizes a diameter expressed by the numerical aperture 1·0, the second one 1·28, and the highest 1·43, which can be actually verified by the help of an auxiliary Microscope.

Murray and Heath's Polarizing Apparatus.—Mr. R. C. Murray has devised a plan of applying the analyzing Nicol in a sliding-box fitting, to be attached to the microscope-tube *as a nose-piece*, by which means the prism can be readily shifted in or out of the field for examining rock-sections, &c., by ordinary or polarized light.

Fig. 48.

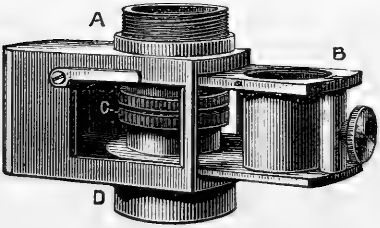


Fig. 49.

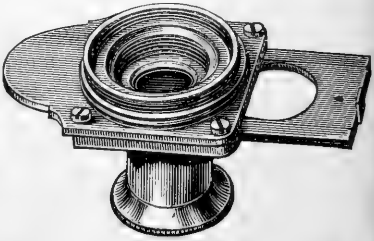


Fig. 48 shows the device ($\frac{2}{3}$ size); A is the "Society" screw for attachment to the tube, while the objective is screwed into D; B is the sliding-box, the tube C carrying the Nicol's prism, that can be rotated by the double-milled edge shown. When the analyzer is not required it can be pushed "home" in the box, and the other tube then leaves the axis of the Microscope free. A spring at the side slightly keys the sliding-box in the two positions required, that is, either using the Nicol or not. The polarizing prism (Fig. 49) is mounted in a somewhat similar manner for use beneath the stage, the milled edge below giving the rotation.

Notes on Aperture, Microscopical Vision, and the Value of wide-angled Immersion Objectives.*

I. The Aperture Theories.—Apertures exceeding 180° angular in air.—The true notation for Aperture.

1. *The two Theories of Aperture.*
2. *"Dry" and "Immersion" Objectives.*
3. *Definition of "Aperture."*
4. *Increase of Aperture with the increase in the density of the Medium. —Apertures exceeding* 180° *angular in air.*
5. *The Photometrical Test.—Supposed Identity of the Hemispheres in different Media.*
6. *The "Resolution" Test.*
7. *The "Angular Grip."*
8. *Numerical Aperture.*

II. Angular-Aperture Fallacies.

1. *The Hemisphere Puzzles.*
    - (a) *The Convex Hemisphere.*
    - (b) *The Concave Hemisphere.*
    - (c) *The Hemisphere as a Condenser.*
2. *Illumination Fallacies.*
3. *Power of the Plane Surface of a Lens.*
4. *The Diagram Fallacy. (The Stokes immersion and the Shadbolt dry Objectives.)*
5. *Fallacies in Practical Construction.*
6. *"Not Image-forming Rays."*
7. *"Only a Question of Nomenclature."*

III. Photometrical Questions connected with Aperture.

1. *Difference of Radiation in the same Medium.*
2. *Increase of Radiation in Glass, Oil, &c.*

IV. Microscopical Vision and the Delineating Power of Objectives.

1. *The Abbe Theory of Microscopical Vision.*
2. *The Delineating Power of Objectives and Aperture.*

V. The Value of wide-angled Immersion Objectives.

I. The Aperture Theories.—Apertures exceeding 180° angular in air.—The true notation for Aperture.

During the recent discussion on Aperture many of the old fallacies reappeared, with which we propose therefore to deal in the following notes. It should, however, be distinctly understood that we do so from a wholly impersonal point of view. So far from it being our intention to reflect upon those who gave expression to the views referred to, we recognize that they have in fact thereby done a very useful service, as it has enabled explanations to be given which will serve to prevent any such difficulties disturbing the minds of future generations of microscopists.

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* Taken as read 9th February, 1881. See p. 365.

There are now so many of the Fellows who recognize the errors of the angular aperture view, that we are almost afraid they will be disposed to grudge the space given to these notes. We are, however, obliged to look at the matter a little from our own side of the table. So far as we are aware, there does not exist in print any attempt to deal in a connected form with the old theory of aperture, or to point out how it is opposed not merely to optical laws which may be considered to be more or less abstruse, but to those simpler principles which lie at the very threshold of any understanding of the Microscope as an optical instrument. Moreover, the true view of the aperture question (first propounded by Professor Abbe) has been disseminated amongst the Fellows almost entirely by verbal or written communications; and as it is to our lot, as a rule, that it falls to reply by word of mouth or by correspondence to requests for explanations, it will be a great advantage to us, and of corresponding benefit to the Society, that we should be able to refer inquirers to printed statements in the Journal, whereby much time and labour will in future be saved which can be devoted to other matters.

It will also serve to show what are the points that must be met in any attempts to prove the validity of the "angular" theory of aperture; whilst so far as regards angular aperturists, they can but rejoice on the principle of the invocation, "Oh that mine adversary had written a book!"

(1) **The two Theories of Aperture.**—There have been two conflicting theories of aperture, the one known as the *Angular* theory (which formerly had prominent supporters and was recently revived by Mr. Shadbolt *), and the other the *Numerical* (or Abbe †) theory.

The essential feature of the former theory is that it regards the *angle* only of the radiant pencil, and claims that not only may two apertures be correctly compared by the angles in the case of the same medium, but also when the media are different. An angle of 180° in air is considered to represent therefore a large excess of aperture in comparison with only 96° in water or 82° in oil (or balsam), denoting in reality the *maximum* aperture of any kind of objective, which cannot consequently be exceeded, but only equalled, by 180° in water or oil.

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* See this Journal, iii. (1880) pp. 1089–92, and i. (1881) pp. 150 and 154–72, where a full exposition will be found of the old view of aperture and of the action of immersion objectives. See also Engl. Mech., xxxii. (1880) p. 115.

† This theory is known as the "Abbe" theory of aperture, from its having been first promulgated (some years since) by Dr. E. Abbe, one of the professors at the University of Jena, and an Honorary Fellow of the Society—the first living authority on microscopical optics. We are glad to acknowledge our great indebtedness to him not only for the first exposition of the erroneous view so long held by microscopists on the aperture question, but also for much other instruction in optical matters of the utmost value in connection with the theory of the Microscope. Indeed, these notes may be taken to be, as it were, "lecture notes" of instruction given by him, the "lectures" not, however, having been oral, but contained in a somewhat voluminous correspondence with ourselves and others extending over several years.

That, in fact, a radiant pencil has exactly the *same* value, for equal angles, whatever the refractive index of the medium in which it may be.

The essential feature of the second theory is that it does not regard the angle only, but takes account of fundamental optical phenomena actually existing in nature, which the old theory entirely overlooked, whereby it is shown that even when the medium is the same, apertures cannot be compared by the angles only of the radiant pencils, but by their sines; whilst when the media are different, the refractive indices of those media must also be considered. An angle of 180° in air is therefore equal in aperture to one of 96° in water or 82° in oil, and represents consequently not a maximum, but much less than the aperture which is represented by the same angular extension in water or oil.

A radiant pencil has therefore an entirely *different* value for equal angles in media of various refractive indices.

It will be seen that the points of distinction between the two theories are by no means differences of nomenclature only,* but turn upon fundamental physical and optical principles the very existence of which is wholly denied by the "angular" theory; the point of essentially *practical* importance to the microscopist, who may require for his observations large aperture, being that, contrary to the angular view, immersion objectives *have* apertures in excess of the maximum attainable with a dry objective, that is, exceeding 180° angular in air.

The "aperture question" will ever hold a most prominent place in the history of the Microscope, representing as extraordinary a series of mistakes as were ever committed in any branch of science, and in which (down to comparatively recent times) both the leaders and the rank and file were equally involved. "Aperture" may be said to have been the "*Haschisch*" of the microscopist; when *that* has formed the subject of consideration, the simplest and oldest established optical principles have not been disregarded merely, but their very converse tacitly assumed, as if the great optical physicists of this and the previous century had never lived, or had written nothing that was worthy of consideration!

(2) "Dry" and "Immersion" Objectives.—To understand the question of aperture, it is of course necessary in the first place to have a clear idea of the essential difference between a "Dry" and an "Immersion" objective. Some misapprehension exists on this point, as we have been assured that we must be entirely wrong in asserting that a dry lens can never have as large an aperture as a wide-angled immersion objective,† for said our critic, "I can show you that if

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* We deal hereafter more in detail (see II. "Angular-Aperture Fallacies," No. 7) with the notion that the difference between the two views is "only a question of nomenclature"!

† By "wide-angled immersion objective" is always meant one whose angular aperture exceeds twice the critical angle of the medium used for immersion, i. e. $>$ 96° for water and $>$ 82° for balsam or oil.

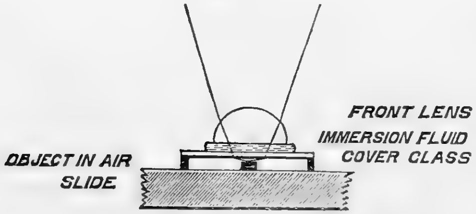
you take a dry objective and give it a different back lens, and put a drop of water or oil between the front lens and the object, it will have as large an aperture as an immersion objective"!

Dry and immersion objectives do undoubtedly differ in their construction, but the same objective may be used at one time as a true dry objective and at another as a true immersion objective without any alteration in its lenses, so that differences of construction do not constitute what logicians would call the "specific differentiation" between the two kinds of objectives. When we speak of a dry or air objective, we mean essentially an objective which is used *with a film of air intervening at some point between the object and the first surface of the objective.* (The object, therefore, being either in air or mounted in balsam or other fluid with air above.) While by an immersion objective we mean essentially one in which no film of air so intervenes, but the *whole space between the object and the first surface of the objective is occupied by a substance whose refractive index is greater than air.* (A condition which of course implies that the object itself must be immersed in fluid or closely adhering to the cover-glass.)

As the cardinal point of the angular theory is that a dry objective of 180° angular aperture (used on an object in air) represents the maximum aperture that is possible, theoretically or practically, it is desirable to appreciate at the outset that it is possible to have a dry objective of angular aperture very closely approaching 180°. When a comparison is made between a wide-angled immersion objective and a dry objective of nearly 180° angular aperture, it is objected* that no such objective can exist, for it is impossible to bring the surface of the lens in close contact with the object, or that even if we could, there "would be no working distance and no possible adjustment to suit varying sights."

But a homogeneous-immersion objective used with an object which is in air and close (but not adhering) to the cover-glass, as shown in Fig. 50, is a *dry objective*, for a film of air is interposed above the object. Further, by reason of the intervention of the immersion fluid between the front surface of the first lens and the cover-glass, *the under side of the cover-glass has become in effect the front surface of the objective;* the object may be close to this front surface, and there is of course full capability of adjustment for different sights by increasing or lessening the distance between the objective and the cover-glass. We have therefore a dry objective of angular aperture closely approximating to 180°, and with very slight spherical aberration in consequence of the exceeding

FIG. 50.



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* See this Journal, iii. (1880) p. 1090.

thinness of the intervening film of air. The appreciation of the fact that it is a *dry* objective has apparently been obscured by the existence of the *immersion fluid* between the front lens and the cover-glass.

A practical advantage of having such a dry lens is that it enables us to consider the question of the surplus aperture of wide-angled immersion lenses (in excess of that of 180° angular in air) with reference to the case of *one and the same objective*, which in several ways simplifies the consideration both experimentally and otherwise. Without altering the illumination or removing the objective from the Microscope, but simply shifting a slide from that part which contains a dry object to that which has a similar object mounted in balsam, the difference in the aperture of the objective under the two conditions is at once made visible.

(3) Definition of "Aperture."—The first doubt on the mind of an angular aperturist is whether the numerical aperturist is not a person of such confused ideas, or at any rate of such neglected optical education, that it must be a waste of time even to hear what he has to say. This is a perfectly genuine doubt, because the angular aperturist hears his opponent speak of (1) an aperture in *excess* of that of 180° angular in air, and (2) of a balsam-angle of 82° being the "optical equivalent" of an air-angle of 180°, so that he assumes the numerical aperturist not to be aware, 1st, that there can be no *angular* aperture beyond 180°, and, 2nd, that a part can never be equal to a whole!

When he is satisfied that the numerical aperturist does not dispute either of these propositions, and that he lays stress upon "aperture" as opposed to "angle," his next suspicion is that some *double entendre* must lie hidden in the word "aperture."

There is no reason for objecting to the definition of the term "aperture" insisted upon by most angular aperturists, viz. as meaning not resolving-power, but essentially "*opening*."* In acting upon this definition, however, and attempting to estimate the relative "openings" of objectives, only the pencils *admitted* into the objective from the front have hitherto been considered. The alternative view is now so obvious, that it seems strange it should not have occurred to any one before Prof. Abbe—notwithstanding the number of minds that have been at work on the aperture question at various times—to regard not the admitted but the *emergent* pencils (between which he established the existence of a general relation). Whether we take the pencil which *emerges from* the objective or that which is *admitted into* the objective, is obviously the same thing as regards the present question, for no one will contend that anything can emerge that has not first been admitted. The great and obvious advantage in dealing with the emergent pencil is that it is always in air, and so the perplexities are eliminated which have enveloped the consideration of the admitted pencil, which may be in air, water, oil, or other substances of various refractive indices.

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* There are some, however, who treat the idea of "opening" as of secondary importance in regard to aperture, and as giving only greater illumination, which can of course be obtained otherwise!

Aperture therefore, as meaning distinctly "opening," may be properly defined by reference to the diameter of the pencil (at its emergence from the back lens) which the objective has taken up from any given point of the object and collected to a focus at the conjugate point of the image. Not, of course, the *absolute* measure of this diameter or "opening," for that would class a 1-inch objective as of larger "aperture" than a $\frac{1}{2}$-inch, but the *relative* opening—that is, the opening in relation to power or "focal length."

Thus, if two objectives are of the *same* power, the one that has the larger opening—that is, the one which transmits from the object to the image the wider pencil—has the larger aperture. If, however, the two objectives are of *different* powers, then the one which has the wider pencil relatively to its focal length has the larger aperture.

If Fig. 51 represents diagrammatically an objective of given power (or focal length*), its aperture is obviously reduced if a stop is inserted at the back of either of the lenses. The power remaining the *same*, the aperture varies with the emergent pencil.

Fig. 51.

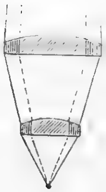

Fig. 52.

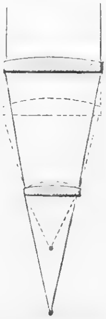

Fig. 53.

The case of *different* powers and the same or different emergent pencils is shown in Figs. 52 and 53.

If an objective of lower power (see Fig. 52) is compared with the previous one (indicated by dotted lines), the emergent pencil may remain the same, but the aperture is obviously smaller in the case of the lower power.

If an objective of twice the power of the first is taken (see Fig. 53), the emergent pencil may be only half the diameter, but the power being doubled, the aperture remains the same.

(4) Increase of Aperture with the increase in the density of the Medium.—Apertures exceeding 180° angular in air.—It is, of course, common ground with both theories of aperture that when the medium remains the same, as in the case of dry objectives, the larger the angle of the admitted pencil the larger the aperture, a

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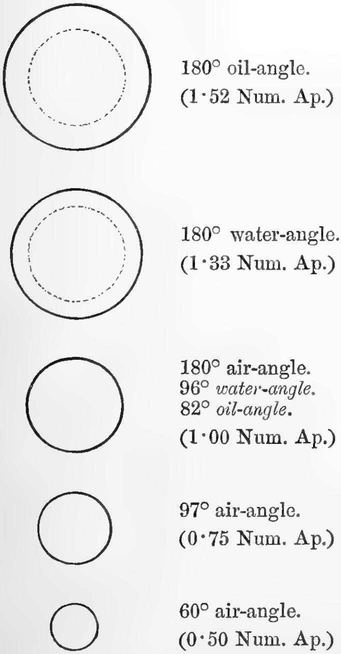
* In these diagrams there is, of course, no line which represents visibly the "focal length" of the objective, as in the case of a *single* lens. In a *compound* objective the "focal length" is arrived at by comparing the objective with a single lens of *identical power*, and the expression of the focal length of the single lens is taken as that of the objective.

dry objective of 180° air-angle having a larger aperture than one of 100° and the latter than one of 50°. The most important of the differences between the two theories arises, however, when for air is substituted a medium of greater refractive index, such as oil. This constitutes the special difficulty of the angular aperturist, for having in his consideration of aperture confined himself to the angles in front, and those being of course always limited to a maximum of 180°, he is not unnaturally led to consider 180° in air to be an absolute limit as regards aperture which cannot be surpassed by any kind of objective, a limit, moreover, imposed by fundamental natural laws in whichever way the matter is regarded.

Fig. 54.—Relative diameters of the (utilized) back lenses of various dry and immersion objectives, of the same power, from an air-angle of 60° to an oil-angle of 180°.



If we examine the emergent pencils corresponding to the different angles, and, for simplicity, take objectives of the same focal length throughout, we see that the diameters of the emergent pencils of the *dry* objectives enlarge with the increase in the angles of the admitted pencils (though, as will be shown hereafter, not in the same proportion), the maximum diameter for a dry objective being obtained when the angle is 180°. If now the dry objective of 180° is replaced by an oil-immersion objective of 82°, and the angles at the radiant are increased (from 82°) as those of the dry objective were increased (up to 180°), the plain fact is that the emergent pencil *goes on enlarging in the same manner as before.* Thus if we commence with an air-angle of 10° and proceed by successive additions of 10° up to 180° air-angle, passing then to 82° balsam-angle, and again progressing up to the nearest practicable approximation to 180° balsam-angle, the emergent pencils will show a *continuous increase.** There is no break at the 180° air-angle nor does anything abnormal occur at that point, but we have a regularly progressing series from the lowest air-angle to the highest balsam-angle, the diameter corresponding to the 180° air-angle not being at the top of the series but only two-

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* If the objectives have the same focal length throughout, then, as before explained, the absolute diameter of the emergent beam is all that need be regarded; while if the focal lengths vary, it is the ratio of the diameter to the focal length that must be considered.

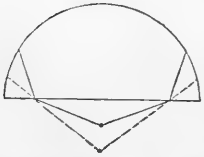
thirds of the way up, and being identical with that corresponding to 82° balsam-angle.

The diagram, Fig. 54, will serve to indicate more plainly the progressive increase in the diameters of the emergent pencils of objectives of any given power from an angular aperture of 60° in air to the highest oil-angle of 180°, and it will be seen that the pencil which emerges from a dry objective of 180° air-angle is *less* in diameter than that emerging from a water objective of 180° water-angle, or an oil objective of 180° balsam-angle, in the ratio of 1·0 to 1·33, or 1·52, the intensity of the light being approximately * the same in all. The dotted circles in the latter two cases are of the same size as that corresponding to the 180° air-angle and are added for ready comparison.

The diameter of the pencil emergent from the dry objective is, moreover, found to remain the same whether the object is mounted dry (the radiant pencil being then of large angle) or in balsam (with a much reduced angle at the radiant), so that the fallacy of the notion that the balsam cuts down not merely the *angle* but the *aperture* also becomes apparent.

When the fact of this regular increase is recognized, it is endeavoured to avoid the necessary consequence of the admission by alleging that although after the 180° air-angle is reached the emergent pencil still increases, yet that such increase does not mean the same *above* the 180° as it did *below*, for that when 180° air-angle is passed, and the balsam-angle of 82° substituted, the plane surface of the dry lens no longer exercises any reducing effect—the large air-angles in front of the lens are no longer compressed within 82° in the lens, with a necessarily reduced emergent pencil, but are allowed to expand to their full natural extent, with a proportionately enlarged emergent pencil. Thus in Fig. 55 the larger (inner) air-angle in front of the lens is refracted at the plane surface on its entrance into the glass, and becomes less than 82°. The smaller (outer) angle, assuming oil to have been substituted for air, is not reduced by refraction at the first surface, but passes into the glass with its original angular extension. The larger emergent pencil is therefore, it is supposed, fully accounted for without there being necessarily any larger aperture in the proper sense of the term!

Fig. 55.



One of the plainest of optical considerations disposes of this idea of the action of the plane surface; for, on abolishing the refraction at the *plane* surface of a dry lens by substituting a *concave* one, it is seen that the relative "opening" of the lens remains precisely the same, and is not greater.†

As, therefore, in regard to the measure of the "openings" we

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* That is, less only the loss of 10 or 12 per cent. by reflection at the first surface of the front lens.

† See II. "Angular-Aperture Fallacies, No. 1—The Hemisphere Puzzles, (*b*) the Concave Hemisphere."

have a continuous series from the smallest air-angle to an oil-angle of 180° (the air-angle of 180° being by no means a maximum), it is obvious that the only true and scientific notation for the comparison of apertures must necessarily be progressive also, and that no justification can be found, even as a matter of convenience, for the adoption of one which first advances from 1 to 180, and then instead of going forward goes *back* to 96 and for a second time to 180, then back once more to 127, and on for the third time to 180. If nothing more could be said against such a notation than its want of scientific precision, it might be allowed to pass with only an expression of surprise that any one could desire to retain it, but the mischief of the notation goes beyond any question of taste merely, in that it misleads the microscopist into supposing that the second and third 180°, being the same figures, represent essentially the same aperture, and so obscures the one important and practical point in connection with aperture.

Whilst the fact of the progressive increase in the diameter of the emergent beam, i. e. in the number of rays *emitted* by the objective at its *back* surface, might have been supposed to be abundant proof of itself that there must have been a similar increase in the number of rays *admitted* from the object by the *front* surface,—sufficiently disposing therefore of the principle on which angular aperture is based, and necessarily leading also to the recognition of the proper notation for aperture,—it is rarely that the angular aperturist is content with this mode of dealing with the matter. He considers that "his points" have not been directly met, which he more than suspects is due, not to the fact that they have no basis, but because they are inconveniently sound.

Before, therefore, passing to the determination of the true aperture notation, it will be desirable to show that 180° angular aperture in air does not in fact represent any natural limit or maximum, either (1) *photometrically*, or in regard to the *number of rays;* or (2) as a question of *resolution;* or (3) by virtue of what is known as "*angular grip.*" The fact also that the use of the angular expression is misleading and erroneous even in the case of the same medium, may conveniently be shown at the same time.

(5) The Photometrical Test. — Supposed Identity of the Hemispheres in different Media.—The point which the angular aperturist almost invariably takes up first is the photometrical one, as he considers that to furnish the most unassailable proof that 180° in air represents a "whole" which may be equalled but never exceeded.

With the same fixed illumination, 180° in oil cannot, he supposes, represent anything in excess of 180° in air as regards *quantity of light*, and pencils of any given angular extension (say 82°) in oil are necessarily only equal, therefore, in that respect to the same pencils in air. As there can be no more than the hemisphere in angular measurement, and as he assumes radiation to be the same in all media, it is self-evident, he thinks, that with the hemisphere in air we have a *whole* of light, beyond which there can be nothing. This whole can approximately be taken up by a dry lens, and being the whole, it is absurd, he contends, to speak of a water-immersion receiving *more*, and still more absurd to speak of an oil-immersion receiving *more* than that still. The numerical aperture notation, therefore, which gives a maximum of $(1 \cdot 0)^2$ for the dry objective, $(1 \cdot 33)^2$ for the water immersion, and $(1 \cdot 5)^2$ for the oil immersion, is, he thinks, not only manifestly erroneous but misleading on a vital point.

The simple answer to this view is that the angular aperturist has overlooked a fundamental optical principle, which lies at the root of any such a photometrical question, viz. that the radiation of light from an object in air, water, or oil is not identical,* but that the whole hemisphere of radiation in air is to the whole hemisphere of radiation in water or oil as the squares of the refractive indices of the media, i. e. as 1 to $(1 \cdot 33^2 =)$ 1·77 and as 1 to $(1 \cdot 5^2 =)$ 2·25. The quantity of light in pencils of different angles must be compared therefore not simply (as in the case of the same medium) by the squares of the sines of the semi-angles $(\sin u)^2$, but by the squares of *the sines multiplied by the refractive indices*, i. e. $(n \sin u)^2$.†

We have dealt with this photometrical suggestion as propounded,‡ but at the same time it must be obvious that mere quantity of light alone cannot be a sufficient basis on which to rest aperture. If it were, it could be very readily disposed of on either view of the aperture question. If the angular aperturist pointed out that when the object is in balsam and air above the cover-glass a portion of the light from the object (which is admitted when it is in air) is lost by internal reflection at the cover-glass (see Figs. 61 and 62), it would only be necessary to increase the source of light and the lost amount would at once be recovered. If, on the other hand, it was the numerical aperturist who rested the advantage of the immersion objective as regards aperture simply on the increased quantity of light which he obtained by the use of oil (say $2\frac{1}{4}$ times as great as with air), all that his opponent would have to do would be to take care and use a lamp *three* times as bright with his dry objective, and he would then have beaten the immersion objective! Or, if he used an electric light, his dry objective would of course (on the view supposed) have an "aperture" enormously exceeding that of the immersion objective with only an ordinary lamp! No increase in the amount of the illumination, however, can make a dry lens equal in performance (as regards the special function of aperture) a

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* See further on this subject, III., No. 2, "Increase of Radiation in Glass, Oil," &c.

† As will be seen *infra*, p. 321, $n \sin u$ is the expression for "numerical aperture."

‡ See this Journal, *ante*, p. 150: "If they had a radiant point, whether it were "immersed in air or balsam, or any other medium, the quantity of rays from such "radiant point must be the same identically whatever the medium was;" and p. 155: "It is presumed no one will be found hardy enough to contend that the "total amount of light emitted from a radiant point under a given fixed illumina- "tion would be greater if the said radiant point were in oil or any other dense "transparent medium, than if it were in air. In point of fact we may regard "this total amount of radiant light as a fixed quantity, while the illumination of "the object remains unaltered."

wide-angled immersion lens, and difference of light cannot therefore be the *root* of the difference between the two systems.

A mode in which "quantity of light" *may* legitimately come into account in the aperture question is this:—Take a homogeneous-immersion objective of wide aperture, and use it first as a dry lens of large air-angle (say nearly 180°), and then as an immersion lens of smaller balsam-angle (say 134°). On focussing the objective on the object, and observing the emergent beam at the back, a *smaller* circle will be seen in the former case than in the latter, the two being, however, within a little (the loss by reflection) of the *same intensity.* If the diameter of the smaller circle be taken as 1, that of the larger circle will be equal to 1·4, and the amount of light received by the image in the two cases will be therefore in the ratios of the squares of the diameters, that is, as 1 to 1·96. If, then, we have two objectives of the same focal length, and one is found to take up from the object and transmit to the image a greater quantity of light than the other, the latter being placed in the most favourable circumstances of which it is capable, and the source of light remaining unaltered, it is obvious that the aperture of the former must be larger than that of the latter.

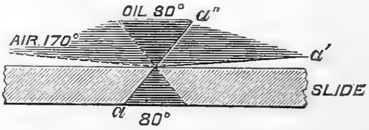
There is, however, another way in which angular aperturists sometimes put the consideration of the hemispheres in different media, which from one point of view is more rational.

Disregarding mere quantity of light as a criterion, and looking only to the *number of rays* in the plane angle, it is said that the number in angles of, say, 180° and 82° in air are equal to those in angles of the same number of degrees in oil. The number, therefore, in the pencil of 80° in Fig. 56 if oil or balsam is above the slide, is supposed to be less than those in the pencil of 170° if air is above.

This view is, however, as fallacious as the preceding.

If we take the case of *refraction*, then one of the most fundamental of optical principles shows that the *same* rays which in air occupy the whole hemisphere of 180° are compressed in a medium of higher refractive index within a smaller angle, viz. twice the critical angle. If in Fig. 56 the object is illuminated by an incident cone of rays of nearly 82° within the slide, and the slide has air above in the first case and oil in the second, it is obvious that the *same* ray which is incident on the object at nearly 41° will always emerge in air at an angle of nearly 90° (a'), and in oil at nearly 41° (a''), so that the same rays which in air are expanded over the whole hemisphere are compressed into 82° in oil, and therefore rays beyond 82° in oil must represent surplus rays in excess of those found in the air hemisphere.

FIG. 56.



If, on the other hand, the case of *diffraction* is considered, then Fraunhofer's law shows that the *same* diffracted beams which in air occupy the whole hemisphere (Fig. 57), are in oil compressed within an angle of 82° round the direct beam (Fig. 58), so that there is room for additional beams.

On this form of the angular aperture view again, therefore, the number of rays in equal (plane) angles of air, water, and oil, are seen to be as the refractive indices, that is, as 1·0, 1·33, and 1·5, and different angles are compared by the values of $n \sin u$.

Fig. 57.

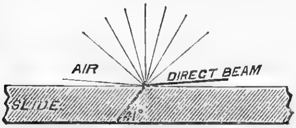
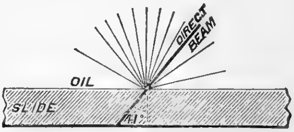


Fig. 58.



We may also point out here that even in the case of the pencils being in the *same* medium (as air), the angular aperturist, in insisting that the angles are a true measure, falls into what was formerly a very general mistake among microscopists, viz. the supposition that from a luminous surface-element there is equal intensity of emission in all directions. If this were so, then of course a given portion of the pencil taken close to the perpendicular would be identical with another portion taken at a distance from the perpendicular, provided only that the angular extension of each portion was equal. A pencil of 60° round the perpendicular (that is, of 120° angular extension) would contain 3·8 times the amount of light of one of 30° round the axis (that is, of 60° angular extension), the contents of the solid cones being as 1 : 3·8. A pencil would thus be represented by Fig. 59.

It has, however, been established for more than 100 years that this view is not correct, but that, on the contrary, the emission of light is greater according as it takes place closer to the perpendicular, decreasing towards the horizon with the cosine of the obliquity of emission, so that the pencil is not correctly represented by Fig. 59 but by Fig. 60.

Fig. 59.

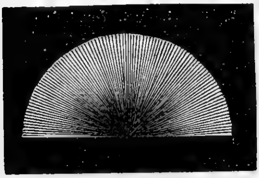
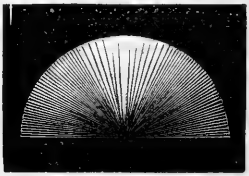


Fig. 60.



When, therefore, the same medium is alone considered, the pencils must be compared by the squares of the *sines of the semi-angles*—that is, by $(\sin u)^2$. A pencil of 120° (60° round the perpendicular) does not therefore contain nearly four times the amount of light of one of 60° (30° round the perpendicular), but three times only.*

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* On this subject see further, *infra*, III., No. 1, "Difference of Radiation in the same Medium."

One of the more important *practical* mistakes which arises from this error may be seen in the case of the higher-angled objectives, to which we refer hereafter.*

From the erroneous assumption of the identity of radiation in different media spring innumerable fallacies. When in the old theory of the solar system the earth was believed to be the centre, with the sun and planets revolving round it, all kinds of complicated phenomena appeared to exist, necessitating equally complicated explanations, which gave rise to inextricable confusion. As soon, however, as the sun was made the centre, the complications existed no longer and required no explanation. In exactly the same way the angular aperturists are misled. They not only miss the whole point of the superiority of immersion objectives, viz. their larger apertures, but in consequence of missing it, and yet being obliged to recognize that they have advantages, they are induced to propound the greatest absurdities.

For instance, some will say that the advantage of immersion objectives consists almost entirely in their increased working distance and in their dispensing with the necessity for a correction collar.

Some, discovering that there is a vast increase of light with immersion objectives, explain their value to rest exclusively on the reduced amount of reflection at the plane surface of the objective, which in the case of the dry lens is said to reflect back a great part of the light. These, through the erroneous assumption with which they started, have been diverted from working out the calculation, which shows the loss of light to be only about 10 to 12 per cent.†

Others deny that immersion objectives can have any substantial advantage as regards aperture over dry objectives used on objects which are in air, as the latter radiate light up to the whole 180°, of which the dry lens can take up, say 170°, so that there is little or no room left for any improvement on the part of the immersion objectives, which are therefore supposed to show superiority over dry lenses *only in the case of the latter being used on balsam-mounted objects!* This is the view which is most frequently—we may say invariably—propounded, as it appears to be the most self-evident.

Thus, if Fig. 61 represents a pencil of 170°, radiating from an object in air, a dry objective of maximum aperture may take it up. If, however, the object is mounted in balsam, it is supposed to be so "environed" that by far the larger part of the original pencil is reflected back from the cover-glass (see Fig. 62); the dry lens, it is said, is as ready as ever to take up the original 170°, but cannot now get that pencil as it could before, when the object was in air. All it

FIG. 61.

FIG. 62.

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* See *infra*, II. "Angular-Aperture Fallacies," No. 5, "Fallacies in Practical Construction."

† See *infra*, III., No. 1, "Difference of Radiation in the same Medium."

can get is the *smaller* pencil of 80° in balsam (equal, according to the angular aperture view, to 80° in air), and it is therefore supposed to be placed in circumstances in which its full powers cannot have play, in consequence of the object being in fault. The immersion objective now steps in, and by virtue of the immersion fluid above the cover-glass restores the old condition of things when there was no question of critical angles, and so is able ultimately to take up a pencil equal to, but not exceeding, that which the dry lens took up when the object was uncovered. The mistake of the numerical aperturist is (it is imagined) clear. He has treated the 80° in Fig. 62 as if it were precisely the same thing as the 170° of Fig. 61, and so is of course able to show something *more* than that when the immersion lens is used. When he thought, however, that he had 170°, he had really only 80°!

As soon as the non-identity of the whole hemispheres of radiating light is appreciated, the theory built up by the angular aperturist on this aspect of the aperture problem at once tumbles to the ground; his hemisphere in air is indeed still a *whole hemisphere*, but not a *maximum* beyond which there can be nothing more, as it is in fact exceeded by the hemisphere of water, and the latter again by the hemisphere of oil. The notion that the balsam-mounted object in Fig. 62 is guilty of some fault which cuts down the light coming to the dry lens, is proved to be groundless. The quantity of light or number of rays in the air pencil of 170° of Fig. 61 is seen to be not greater than, but only equal to, that in the balsam pencil of 80° of Fig. 62; that the balsam 170° of Fig. 62, which had been assumed by the angular aperturist to be the equivalent of the air pencil of 170° of Fig. 61, is in fact much *more*.

If, therefore, *quantity of light* were, as the angular aperturist supposed, a proper, and not an insufficient basis for determining the aperture question, the angles alone cannot be taken for the determination, as the quantity in any given angles in air, water, or balsam must be compared by the values of $(n \sin u)^2$, n being the refractive index of the medium and u the semi-angle of aperture. The *number of rays* in the plane angles are compared also by the values of $n \sin u$. In neither case does 180° in air represent a maximum.

(6) The "Resolution" Test.—The contention of the angular aperturist here is that the resolving power of an objective must vary in accordance with the angle, and reach a maximum at an air-angle of 180°.

In the case we have just considered, he had no excuse for not recognizing the obvious fact that quantity of light was an entirely insufficient basis on which to discuss aperture, or for not performing the simple experiment ready at his hand, which would have showed at once that the light transmitted from the smaller balsam pencil was not in fact, as he had assumed it to be, less than that transmitted by the larger air pencil. In the case, however, of the resolving power of objectives, there is somewhat more excuse, for whilst it is seen that the resolving power increases with increasing angles in the case of a dry objective, there *seems* to be a falling off when for the dry angle of 170° is substituted the balsam-angle of 80°.

Thus an oil-immersion objective of 100° angular aperture (1·16 num. ap.) has in reality a greater resolving power than a dry objective of 170° angular aperture (0·99 num. ap.). But when an object is observed, first dry and then in balsam, its structure is much less visible in the latter case than in the former, whence it is concluded that as regards resolving power, at any rate, the greater angle has the greater effect.

The diminished visibility is, however, conditional, and has nothing to do with the resolving power of the objective, as it exists only in the case of those objects whose refractive indices nearly approach that of the medium in which they are immersed, whereby their minute structure is rendered the less distinct. As Mr. Stephenson has pointed out,* the image of the balsam-mounted object has become fainter in consequence of this nearer approximation to equality of the diatomaceous silex and the balsam of the mounting; the markings, whatever they may be, are less pronounced than when in air, the visibility being proportional to the difference between the refractive indices of the object and the mounting medium.

A simple experiment readily shows whether the reduced visibility of the object is due to the cause we have mentioned or to the reduction of the angle. Substitute for the balsam a mounting substance of greater refractive index. The angle is now still *more reduced*, and the object should be still *less* distinct if the view contended for were correct. In fact, it is *more* distinct, and it is obvious therefore that the reduction of the angle has nothing to do with the matter.

Eliminating therefore all exceptional circumstances and dealing with resolving power in its essential conditions, it is found both by experiment and by theory that the resolving power of objectives does not vary, as the angular-aperture theory supposes, with the *angles*.

It is unnecessary to reproduce here the demonstrations which show that the microscopical image of minute objects is not, as was for so long supposed, a *dioptric* but a *diffraction* image, as it is referred to hereafter.† It is sufficient for the present purpose to note that just as a grating produces a central uncoloured image and lateral spectral images of a candle-flame, so a diatom will produce at the back of the objective central and lateral images of the source of light, more and more of the structure being revealed according as a greater number of the diffraction spectra are taken up by the objective. Thus, as we have seen, a dry objective of 180° will give an emergent beam of limited diameter, and will then admit a given number of diffraction spectra on each side of the central uncoloured image. A water-immersion objective of wide angle will give an emergent beam of greater diameter, by means of which additional diffraction spectra on either side may be brought into the field with increased resolution of the object. An oil-immersion objective giving a still larger emergent beam will, in the same way, bring into the field still more diffraction spectra with further advanced resolution. The divergence of the diffraction spectra

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* See this Journal, iii. (1880) p. 564.

† See IV., *infra*, p. 347.

being (in accordance with Fraunhofer's formula) proportional to the sine of the semi-angle multiplied by the refractive index of the medium, $n \sin u$ † is the true measure of the resolving power of an objective; so that 180° air-angle (= 1 num. ap.) represents not the whole (= 1·5 num. ap.) but only two-thirds of the total possible effect as regards resolving power.

Sometimes it is objected, as it was in the recent discussion,‡ that resolving power must not be dealt with in considering aperture. It is somewhat difficult to appreciate how it can be consistently, or even seriously, suggested that resolving power is to be excluded from a discussion of the aperture question from the point of view of *angular* aperture, for even in the height of the predominance of that theory it was resolving power, and resolving power alone, that was always accepted as representing the proper function of increased aperture.

The *true* function of aperture is in fact to be found not merely in resolving power, but in the increased and more perfect *delineating power* of the Microscope (to use Professor Abbe's term), i. e. the power of the Microscope to show things *as they are.* This view is, however, founded on considerations which the angular aperturist necessarily does not accept, and which to him has always been represented only by the more limited term of "resolving power," which is *one* only of the particular manifestations of delineating power. When, therefore, he does not object to the use of the expression of $n \sin u$ as the proper expression for resolving power, he may well be asked to define those *other* benefits, *not* being resolving power, which he contends are attendant upon increased aperture, and for which the *angle* is alleged to be the correct expression.

(7) The "Angular Grip."—Having seen that illuminating power and resolving power vary not as the angles, but as $(n \sin u)^2$ or $n \sin u$, we reach the last point suggested by the angular aperturist in support of the supposed maximum of 180° in air, which has come to be known as the "angular grip" theory. If "angular grip" existed in reality, the use of the angular expression would of course be established, as it must obviously increase with the angles and attain a maximum at 180° whether in air or any other media.

Taking Figs. 61 and 62, and forgetting that it was they themselves who raised the photometrical question or the resolution question and at first based all their argument on that alone, they say, "Your demonstration has not touched the real point at issue, which has nothing to do with greater or less amount of light, or with greater or less resolving power. Is it not clear that the pencil in Fig. 61 is of larger angle than that of Fig. 62."

If it is explained that no objection is intended to be made on that point, and that every one must readily admit that the pencils *are* different as regards angular extension, the angular aperturist exclaims triumphantly, "If you admit that the angular extension of the pencils at the object is different—that the pencil of 180° in Fig. 61 is in that respect larger than the pencil of 82° in Fig. 62—I have proved my case. The angular grip of the object is greater with the 180° than with the

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† i. e. the "numerical aperture."

‡ See this Journal, *ante*, p. 160.

82°. In the one case the light comes with an obliquity of 90°, whilst in the other case it has only an obliquity of 41°, and the object can of course be seen more completely and distinctly by reason of the greater obliquity.* It cannot matter whether the medium is air or balsam; the obliquity *per se* is obviously not altered in the least degree by the change of medium."

For years the ablest and most experienced microscopists in England, and indeed everywhere, accepted the doctrine without question that there *was* a special virtue in the increased obliquity of the light incident on and emanating from the object, and not only so, but pointed out the reason for the (supposed) fact, explaining it to depend upon what were termed "shadow effects," i. e. in the same way as the inequalities on the face are better brought out by oblique than with direct light. This process of discovering a reason for a supposed fact prior to any verification of the fact itself, is only paralleled by the famous problem said to have been propounded by Charles II. to a learned Society—"*Why* does a vessel of water with a fish in it weigh no more than it did when there was no fish?"

About thirteen years ago it occurred to Professor Abbe to investigate the reason for the supposed value of obliquity *quâ* obliquity, and he naturally proposed in the first place to consider anew the grounds on which the view had been based when originated. To his surprise he found that no attempt had really been made to investigate the matter; that there was no theory and no experiment to support the alleged fact, which had been quietly assumed by every one to *be* a fact, no one knew how, except from some fancied analogy to ordinary vision, regardless of the different conditions of microscopical vision, or probably from incomplete generalization from the fact that a pencil of 170° does show minuter structure than a pencil of 80° in the same medium; but that, like the fish problem, it had not occurred to any one that the task of verifying the existence of the assumption should have preceded any reasoning upon it or attempts to explain it.

A long course of experiments extending over several years was undertaken by Prof. Abbe, which established the fallacy of the old view, and by force of the necessity for explaining intelligibly the real specific function of increased aperture, led to the enunciation of the most important theory that has ever been propounded in regard to the Microscope itself, viz. the Abbe theory of microscopical vision to which we refer hereafter.†

The cardinal point in Prof. Abbe's experiments was the discovery that the utilization of increased aperture depends *not on the obliquity of the rays to the object* (as had been assumed), *but on their obliquity to the axis of the Microscope.*

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* Sometimes the *opposite* view is put forward, viz. that by the increased angle of aperture a *less* perfect image of the object is obtained in consequence of the unnatural character of vision with large angles, which is supposed to produce distortion and indistinctness not found in ordinary vision with the naked eye where small-angled pencils are in question.

† See IV., *infra*, p. 347.

It was shown that both theory and experiment may be applied to prove that the mere angular extension of the pencils—obliquity *quâ* obliquity—so far from being of importance, is absolutely indifferent; that the greater obliquity of the rays incident on or emitted from the object is not and cannot be *of itself* an element of the optical performance of greater aperture. If it were, the necessary consequence would be that the same increase of optical performance which is obtained by a greater aperture, must be equally obtained with a lesser aperture, by *inclining* the object to the axis of the Microscope. Now this is of course so in regard to the shadow effects of *coarse elements* which are plainly seen by aperture angles of a *few* degrees. But this is not the performance for which we require aperture; the only essential practical function of increased aperture is to afford vision of *minute* elements or structures which are not seen by small-angled pencils. When, however, we have objects which are not resolved by direct light and in the ordinary position by an aperture of say 80°, but are *readily resolved under the same circumstances* by an aperture of 90°, they are not resolved with the 80°, even if we incline the preparation to any angle, though a few degrees of inclination would give the same increase of obliquity as regards the object which the increase of aperture gave.

The experimental consideration was seen to be supported by theory. Whenever the linear dimensions of objects are reduced to *small multiples* of the wave-lengths, all shadow and similar effects must cease. The reason is similar to that which shows why objects of not more than a few feet in diameter do not give a sensible *acoustic* shadow behind them, but only those whose dimensions are *large* multiples of the sound-waves. The waves of both sound and light *pass round* an obstacle which is not much greater than their length.

The supposed advantage of "angular grip" is also sometimes based on the contention that the increase in obliquity obtained by wide angles produces an effect of "solidity." This idea of solidity obviously arises from the supposition that the different perspective views of a preparation which correspond to the different obliquities produce the same result as if they were seen separately by different eyes, as is the case in the binocular Microscope. In reality the various views are united on one and the same retina, and as the image is nevertheless perfectly delineated, the idea of solidity must be erroneous.

The true effects of obliquity are proved by Professor Abbe's experiments (which every microscopist can try for himself without any apparatus costing more than a few shillings), to depend not on the *angles* but on the *numerical equivalents* of these angles ($n \sin u$), and thus an obliquity of 41° in balsam must have the same effect as an obliquity of 90° in air.

If the angular aperturist is still not satisfied that there can be no virtue in mere obliquity *quâ* obliquity, then it is of course for *him* to bring forward the grounds, whether theoretical or experimental, by which he establishes the virtue of the obliquity—that the large air-pencil of 180°, carrying with it demonstrably no greater quantity of light, and equally demonstrably no more resolving power than the small balsam-pencil of 82°, yet has *some* virtue that prevents the latter being treated as its equivalent. We are entitled to ask *what* this virtue is, and to be shown that it is not a mere fancy. If it is asserted that there must necessarily be a loss in passing from 180° air-angle to 82° balsam-angle (a large difference in angular extension), surely this loss can be shown or defined? At least, some intelligible explanation can be given of its essence and existence—of the optical theory on which it is based or the experiments by which it is supported?

(8) Numerical Aperture.—Having now shown that in whatever way the matter may be regarded the expression of the degrees in the angles is not a correct method of comparing apertures, and that 180° in air is not a maximum, we are in a position to resume the consideration of the notation to be adopted for the proper estimation of aperture, and this it will be seen is essentially numerical aperture, which is however supposed by the angular aperturist to be a fanciful notation, not founded on any known natural phenomenon, so that whether a person adopts it, or continues to use the expression of "angular" aperture, is purely a question of taste, like the adoption of the Fahrenheit or Centigrade scales for the thermometer.

Aperture, in its true and legitimate meaning of "opening," depends, as we have seen, on the ratio between the clear opening of the objective and the power—a ratio which increases progressively from the lowest angular aperture of a dry objective to the highest angular aperture of an oil-immersion objective. The expression for the ratio of the semi-diameter of the emergent pencil to the focal length is $n \sin u$, n being the refractive index of the medium and u the semi-angle of aperture. It is simply this expression which is the *numerical aperture*, and which is therefore the true measure of the relative apertures of objectives of all kinds.

We have also seen that whether we consider the amount of light in the pencils, the number of rays in the plane angle, or the resolving power, it is $n \sin u$ (or its square) which affords the only correct comparison.

The expression n sin u.

We add here one of the forms of the deduction of the expression $n \sin u$ which, though not the most strict, is one of the simplest. It establishes two points. 1st. That the angle alone ($2u$) can never correctly define aperture, for equal apertures always require equal values of $n \sin u$, and different apertures different values; so that this expression (i. e. a function of the semi-angle compounded with the refractive index of the medium, and not the angle itself) is necessarily the adequate measure of aperture in general; and 2nd, that a dry objective cannot have so large an aperture as a wide-angled immersion objective.

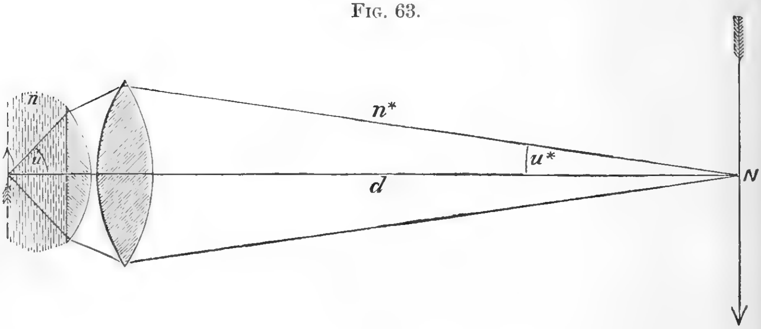
Let Fig. 63 represent any objective collecting a pencil exceeding 82° in balsam with any desired amplification of the image, and any desired distance of the image (i. e. length of tube), let u be the semi-angle of the admitted pencil within a medium of refractive index n ($= 1 \cdot 5$ if it is oil), N the amplification of the image which is always in air, and u^* the semi-angle of the emergent pencil which depicts the image. According to the law of aplanatic convergence †—

$$\frac{n \sin u}{n^* \sin u^*} = \mathrm{N},$$

or, as $n^* = 1$ for air,

$$\sin u^* = \frac{n \sin u}{\mathrm{N}}.$$

FIG. 63.



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† It may be useful to give the history of this law. It has its origin in a publication of Lagrange ("Sur une loi générale d'optique," 'Mémoires de l'Acad. de Berlin,' 1803), where he first showed that there is a fixed relation between the amplification and the divergence or convergence of the rays at any pair of conjugate foci, provided (1) both foci are in the *same* medium, (2) the system is composed of infinitely thin lenses, and (3) the pencils are *infinitely narrow*, i.e. the angles of convergence very small.

The formula then being $\frac{u}{u^*} = \mathrm{N}$ for every system of infinitely thin lenses (n and n^* being equal).

In the famous reproduction (or rather reformation) of the Gaussian theory in the 'Physiologische Optik' (1866), Helmholtz showed that this formula holds good for every composition of an optical system, and for *different* media, n and n^*, on the general supposition, however, of the Gaussian theory—*infinitely narrow* pencils. The generalized law therefore became

$$\frac{n\,u}{n^*\,u^*} = \mathrm{N}.$$

Instead of u and u^* Helmholtz took the tangents of these angles (which is the same thing as long as the angles are very small), and in this shape the proposition first obtained its characteristic feature, showing the existence of a general fixed relation between amplification and divergence or convergence at conjugate foci entirely independent of the elements of the systems, and indicating a different equivalent of equal angles in different media.

The next step was to apply this formula to systems with *wide-angled* pencils; and in 1873 Prof. Abbe signalized the fact that in the case of aplanatic foci the convergence or divergence of the rays does not vary with the angles or with the tangents, but with the *sines*. The same result was proved independently by Prof. Helmholtz by a different method, and was published by him six months after that of Prof. Abbe.

At a later period Prof. Abbe has expressly called attention to the bearing of the law of the sines to the practical performance of wide-angled systems, and

Thus the divergence or convergence of the emergent pencil is completely defined by N, u, and n, without requiring any knowledge of the focal length of the system, or of the distance d at which the image is formed.

Now there is of course loss of aperture (1) when there is a loss of amplification N, while u^* remains the same, and (2) when there is a reduction of u^*, while N remains the same. For these reasons:—With any given distance d of the image from the back lens, $d \tan u^*$ is the clear available semi-diameter of the back lens. If now the objective gives less amplification (at the same distance d) while u^* is not greater, we should have a *lower-power* objective with the *same* clear diameter of the back lens, and this is necessarily loss of aperture. If, on the other hand, the system gives a narrower pencil (diminished u^*) while N is not greater, we should have an objective of the *same power* giving a narrower emergent pencil (i. e. with a *smaller* clear diameter of the back lens), and this is necessarily loss of aperture also.

Therefore, constant aperture requires the condition of constant amplification N for the same distance d (i. e. for the same length of tube) if u^* is the same, and of constant angle u^* of the emergent pencil if N is the same. It follows, therefore, that the remaining element in the formula which relates to the anterior pencil ($n \sin u$) must also be constant; so that there is always loss of aperture whenever the product $n \sin u$ has a smaller value, as this would require either a smaller N or a smaller u^*.

If now in an immersion objective, with balsam or oil in front, u is greater than the critical angle of the medium, $n \sin u$ will be > 1 (for n is $1 \cdot 5$ and $\sin u$ is at least $\cdot 667$). It will be impossible to obtain the same value, if the front medium is changed for *air*, for n being then only $= 1$, $\sin u$ must be greater than 1, that is an angle with a sine > 1, which is absurd!

No alteration of the optical system is of any avail because the formula holds good for every system.

Therefore no dry objective can be equal in aperture to a wide-angled immersion objective in which $n \sin u$ is > 1—i. e. the balsam angle of which exceeds 82°.

It follows also that equal or different apertures always require equal or different values of the expression $n \sin u$, which is therefore the proper expression for aperture in general.

pointed out its connection with the essence of aplanatism. He indicated at the same time a simple experimental demonstration of the law.

For the literature on the subject, see the following:—

Abbe, "Beiträge z. Theorie d. Mikroskops," &c., Arch. f. Mikr. Anat., ix. (1873) p. 420.

Helmholtz, "Die theoretische Grenze für die Leistungsfähigkeit des Mikroskops," Poggendorff's Annal. Jubelband (1874) p. 566.

Abbe, "Ueber d. Bedingungen d. Aplanatismus d. Linsensysteme," 'Carl's Repertorium für Experimentalphysik,' xvi. p. 303. Conf. this Journal, iii. (1880) p. 509.

The formula in question (the outcome of the combination of the Lagrange-Helmholtz law with the law of aplanatic convergence) is the basis of all investigations on dioptrical questions which deal with wide angles.

*

"Diagram" of Numerical Aperture.

Requests have been made to *see* "numerical aperture." There is the same difficulty about this request as about one requiring to be shown the equator, or the meridian of Greenwich, or the North Pole, as all these expressions, equally with numerical aperture, require the aid of the mental rather than the bodily eye. Applying, however, the only method by which the equator, for instance, could be "*seen*," we may refer to the diagram, Fig. 54 (see p. 309), which shows the diameters of the pencils emerging from the back lenses of dry, water-immersion, and oil-immersion lenses with angular apertures of 60°, 97°, and 180° air-angle, 180° water-angle, and 180° oil-angle, assuming the power of all the objectives to be the same. We add here Fig. 64 (on the same scale), which gives the diameter of the back lens of an objective whose front lens is supposed to be made of a substance whose refractive index = 2·5, i. e. about that of the diamond. The dotted circle denotes the aperture corresponding to 180° in air, and the diagram shows therefore the advance in aperture that would be possible if substances of that refractive index could be made available.*

Fig. 64.

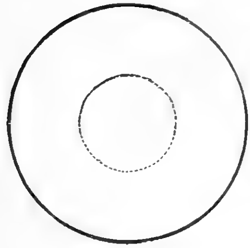

Table of Numerical Apertures.

The table of numerical apertures (calculated by Mr. Stephenson), as inserted on the wrappers, has not previously been given in the body of the Journal; † we now subjoin it for permanent reference. The first column gives the numerical apertures from ·40 to 1·52. The second, third, and fourth the air-, water-, and oil- (or balsam-) angles of aperture corresponding to every ·02 of numerical aperture from 47° air-angle to 180° balsam-angle. The sixth column shows the theoretical resolving power in lines to an inch, the line E of the spectrum about the middle of the green, $\lambda = 0 \cdot 5269\ \mu$ being taken). We have added a fifth column of "Illuminating power" ($= a^2$), though, for the reasons we have given above, it is of comparatively minor importance.

The sum of the whole, therefore, is that if the medium remains the same, apertures are correctly compared by the sines of their semi-angles; or if the media are different, by those sines multiplied by the refractive indices of the media—the value of $n \sin u$, or the numerical aperture, always measuring the relative diameters of the "openings" of objectives, whether the object is in air, water, oil, or any other substance.

Thus with three objectives, one a dry with an angular aperture of 74° (air); a second, a water-immersion of 85° (water); and a third, a homogeneous-immersion of 118° (balsam), their relative "openings" are shown at a glance when the numerical apertures

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* The refractive indices of the cover-glass and the immersion fluid must of course also = 2·5.

† See the first form of the Table, this Journal, ii. (1879) p. 839.

Numerical Aperture. ($n \sin u = a$.)	Angle of Aperture of			Illuminating Power. (a^2.)	Theoretical Resolving Power, in Lines to an Inch. ($\lambda = 0{\cdot}5269\ \mu$ = line E.)
	Dry Objectives. ($n = 1$.)	*Water-Immersion* Objectives. ($n = 1{\cdot}33$.)	*Homogeneous Immersion* Objectives. ($n = 1{\cdot}52$.)		
1·52	..	..	180° 0′	2·31	146,528
1·50	..	..	161° 23′	2·25	144,600
1·48	..	..	153° 39′	2·19	142,672
1·46	..	..	147° 42′	2·13	140,744
1·44	..	..	142° 40′	2·07	138.816
1·42	..	..	138° 12′	2·02	136,888
1·40	..	..	134° 10′	1·96	134,960
1·38	..	..	130° 26′	1·90	133,032
1·36	..	..	126° 57′	1·85	131,104
1·34	..	..	123° 40′	1·80	129,176
1·33	..	180° 0′	122° 6′	1·77	128,212
1·32	..	165° 56′	120° 33′	1·74	127,248
1·30	..	155° 38′	117° 34′	1·69	125,320
1·28	..	148° 28′	114° 44′	1·64	123,392
1·26	..	142° 39′	111° 59′	1·59	121,464
1·24	..	137° 36′	109° 20′	1·54	119,536
1·22	..	133° 4′	106° 45′	1·49	117,608
1·20	..	128° 55′	104° 15′	1·44	115,680
1·18	..	125° 3′	101° 50′	1·39	113,752
1·16	..	121° 26′	99° 29′	1·35	111,824
1·14	..	118° 00′	97° 11′	1·30	109,896
1·12	..	114° 44′	94° 56′	1·25	107,968
1·10	..	111° 36′	92° 43′	1·21	106,040
1·08	..	108° 36′	90° 33′	1·17	104,112
1·06	..	105° 42′	88° 26′	1·12	102,184
1·04	..	102° 53′	86° 21′	1·08	100.256
1·02	..	100° 10′	84° 18′	1·04	98,328
1·0	180° 0′	97° 31′	82° 17′	1·00	96,400
0·98	157° 2′	94° 56′	80° 17′	·96	94,472
0·96	147° 29′	92° 24′	78° 20′	·92	92,544
0·94	140° 6′	89° 56′	76° 24′	·88	90,616
0·92	133° 51′	87° 32′	74° 30′	·85	88,688
0·90	128° 19′	85° 10′	72° 36′	·81	86,760
0·88	123° 17′	82° 51′	70° 44′	·77	84,832
0·86	118° 38′	80° 34′	68° 54′	·74	82,904
0·84	114° 17′	78° 20′	67° 6′	·71	80,976
0·82	110° 10′	76° 8′	65° 18′	·67	79,048
0·80	106° 16′	73° 58′	63° 31′	·64	77,120
0·78	102° 31′	71° 49′	61° 45′	·61	75,192
0·76	98° 56′	69° 42′	60° 0′	·58	73,264
0·74	95° 28′	67° 36′	58° 16′	·55	71,336
0·72	92° 6′	65° 32′	56° 32′	·52	69,408
0·70	88° 51′	63° 31′	54° 50′	·49	67,480
0·68	85° 41′	61° 30′	53° 9′	·46	65,552
0·66	82° 36′	59° 30′	51° 28′	·44	63,624
0·64	79° 35′	57° 31′	49° 48′	·41	61,696
0·62	76° 38′	55° 34′	48° 9′	·38	59,768
0·60	73° 44′	53° 38′	46° 30′	·36	57,840
0·58	70° 54′	51° 42′	44° 51′	·34	55,912
0·56	68° 6′	49° 48′	43° 14′	·31	53,984
0·54	65° 22′	47° 54′	41° 37′	·29	52,056
0·52	62° 40′	46° 2′	40° 00′	·27	50,128
0·50	60° 0′	44° 10′	38° 24′	·25	48,200
0·48	57° 22′	42° 18′	36° 49′	·23	46.272
0·46	54° 46′	40° 28′	35° 14′	·21	45,344
0·44	52° 12′	38° 38′	33° 39′	·19	42,416
0·42	49° 40′	36° 49′	32° 5′	·18	40,488
0·40	47° 9′	35° 0′	30° 31′	·16	38,560

0·60, 0·90, and 1·30, are given, and it is seen also by how much they fall short of, or exceed 1 (= 180° angular aperture in air). Compare with these figures those denoting the angular aperture!

"Numerical aperture," therefore, so far from being a fanciful arbitrary notation, expresses the plain fact that we want to understand, viz. how does the relative "opening" of any given objective—i. e. its aperture or the capacity of the objective for receiving rays from an object—stand in relation to that of another objective (whether dry, water-immersion, or oil-immersion)? Has it the *same* opening, or a *larger* or *smaller* one?

II. Angular-Aperture Fallacies.

We have now dealt with the insufficiency of the angular-aperture theory from all the points on which it has been attempted to base it: showing, 1st, the fallacy of the photometrical test and of the supposed identity of the hemispheres in different media, so that 180° in air does not represent the "whole" contended for; 2nd, that resolving power is not proportional to the angles nor attains a maximum with 180° in air; 3rd, that there is no virtue in greater or less "angular grip"; and 4th, that numerical aperture is the only scientific notation for the comparison of the "apertures" of objectives, using the term in its true sense as the capacity of an objective for admitting rays from an object.

We propose now to deal with some special fallacies of angular aperture which could not be conveniently included in the preceding pages, and the following notes meet some of the difficulties which we have from time to time met with in discussing the aperture question. They are none of them imaginary, but all have actually occurred, and not only so, but have been really felt to be difficulties. It is easy to be surprised, after the explanation is given, that they *could* have appeared as "difficulties"; but as they have occurred more than once already, they are very likely to occur again, and we do not think therefore that the space devoted to them is wasted.

(1) The Hemisphere Puzzles.—

(a) *The Convex Hemisphere.*

This puzzle is now hung up in the Society's Library, and will no doubt be a source of wonder to microscopists of the future that their forefathers could ever have been puzzled by it. It has been suggested in various forms, the most notable of which is the following.

The cardinal fallacy of the angular aperturist has always been the idea that when an object is mounted in balsam the *aperture* of the dry objective is "cut down." Thus the aperture of a dry objective of say a $\frac{1}{4}$ inch of 90° (air-angle) used upon an object in air would, it was thought, be largely "cut down" if the object were placed in balsam, which would reduce the angle at the radiant to say 55°, the air above the cover-glass preventing part of the rays formerly emitted from emerging.* The aperture of a $\frac{1}{4}$-inch immersion objective of 90°

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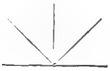
* Cf. Figs. 61 and 62.

balsam-angle would not of course be similarly "cut down," the air-film having been replaced by the immersion fluid.

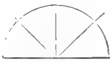
The problem, therefore, was how to restore the "cut down aperture, so that the dry objective with the balsam-mounted object might be brought back again (as it was supposed) to the condition in which it was when the object was dry, with its "undiminished" aperture bearing upon the object.

FIG. 65.



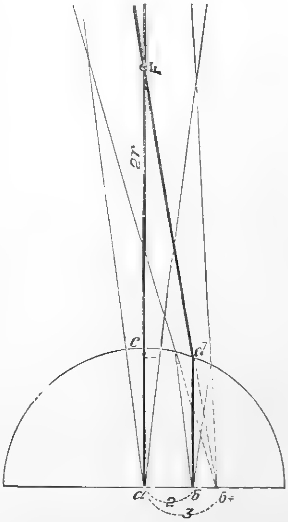
The device hit upon was the convex hemisphere. If Fig. 65 represents the rays radiating from a given point in air, their direction will remain the same (as shown in Fig. 66) if a glass hemisphere is so placed that the radiant point is at its centre. A hemisphere was therefore said to be merely a "radiating lens."

FIG. 66.



A small glass hemisphere was placed over the balsam-mounted preparation, and attached to it with balsam. The angle of the radiant pencil (when the dry objective was focussed upon the object through the hemisphere) was now of course as large with the balsam-mounted preparation as it was originally when the object was dry, and a dry objective was therefore, it was supposed, shown to be capable of having as large an aperture with a balsam-mounted object as with a dry one, all that was required being to bring the object under suitable conditions!

FIG. 67.



Now, strange to say, the propounders of this problem had actually overlooked the fact that the hemisphere magnified the object $1\frac{1}{2}$ times,† so that the objective was no longer a $\frac{1}{4}$ inch, but had been converted into a $\frac{1}{6}$ inch, utilizing, however, not a smaller but the same back

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† The notion that the hemisphere does not magnify evidently originated from considering only the point at the exact centre. From this point all rays pass out radially without refraction.

If, however, not a *point* but an *object* of definite dimensions is considered, as in Fig. 67, it is seen that the hemisphere magnifies in proportion to its refractive index.

The ray ac is transmitted in a straight line, but a parallel ray bd, from an adjoining *excentrical* point, is refracted to the principal focus F. In a lens of refractive index $n = 1 \cdot 5$ the distance of the principal focus from the vertex c is $= 2r$. Therefore the virtual point of divergence of the excentrical pencil from b is transferred to b^*. As:—

$$\begin{aligned} ab^* : ab &= \mathrm{F}a : \mathrm{F}c \\ &= 2r + r : 2r \\ &= 3 : 2. \end{aligned}$$

Thus the line ab is seen magnified $\frac{3}{2}$ times.

combination. Being therefore a higher power ($\frac{1}{6}$ inch) with the same back combination and diameter of the emergent pencil as the lower power ($\frac{1}{4}$ inch) it necessarily had a *larger aperture* than the latter!

We doubt whether there is on record any more extraordinary scientific fallacy than this, propounded as it was with all possible seriousness. That we may not be supposed to intend any personal reflection on *one* side, we may point out that the strangeness is, if anything, enhanced by the fact that the other side did not discover the mistake, and considerations and arguments have been brought forward on the action of such a hemisphere involving the greatest absurdities. Had the true position been appreciated, it would at once have been seen that the angular aperturists had in fact given a clear and simple demonstration that *their own view was wrong*, for they had shown that equal angles in air and glass gave not the same but different apertures, the latter being the larger. The dry objective when used with the hemisphere was of course converted into a true immersion objective, the balsam-angle of which was the same as the original air-angle of the dry objective.

This problem may also be used to demonstrate that an immersion objective can have an aperture exceeding the maximum aperture of a dry objective. For it follows from the formula (p. 322) that no dry front can exist which can be substituted for the hemispherical immersion front without loss of aperture or loss of amplification; for if there could, such a dry front must give an emergent pencil of 90° *under an amplification of* 1·5. The formula, however, shows that the widest cone which can be got out of any lens receiving the rays from air under an amplification of 1·5 is *circa* 82° only.

(b) *The Concave Hemisphere.*

This arises in the following way.

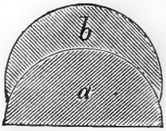
When the angular aperturist is confronted with the fact that the emergent beam of a wide-angled immersion objective is wider than that of any dry objective, he contends that whilst admittedly when the object is in air, a wide emergent beam from an angle of 120° contains more rays than a narrower one from an angle of 60°, yet that when the front medium is changed the increase in the emergent beam can no longer be treated as representing an increase in the rays taken up from the object, for that must necessarily be so in consequence of the action of the plane surface of the front lens, which reduces an air-pencil of 180° into one of 82° only, when it passes into the glass (cf. Fig. 55). With the immersion fluid, however, the reducing action of the plane surface is abolished—the pencils from the radiant are no longer reduced to 82°, but can expand to the fullest extent which the objective will allow, the expanded pencil, however, still representing, it is supposed, no more than the reduced one.

As proof of this view, he considers a dry objective (say $\frac{1}{6}$ inch, of 140° air-angle) with a plane front. The pencil of 140°, after being contracted within the front to one of 76·5° ($n = 1 \cdot 52$), will require, in order to be transmitted through the system, a given clear diameter of the back combination. Assuming the plane surface removed, and a concave one with the centre of curvature at the radiant substituted, he sees that *now* the back combination is fully occupied by a pencil of 76·5°; so that the former pencil of 140° would, in order to be transmitted, require a much wider back lens. Hence he concludes that abolishing the refraction at the front surface produces loss of aperture with one and the same opening, or necessitates increase of opening for one and the same aperture; and as the immersion fluid has the same effect as the substitution of the concave surface of admission, the result must also be the same. The wider emergent beams of immersion objectives are therefore shown, it is supposed, not to denote in reality larger apertures!

He has, however, fallen into the same mistake in principle as that with the convex hemisphere. When the concave was substituted for the plane front the *power* of the objective was *reduced* in the ratio of $n:1$; and as the clear opening is not increased, loss of aperture has arisen from *loss of power*, but *not* from *loss of the refraction* in front. As soon as the original power of the objective is restored by deeper curvatures of the posterior lenses, the original opening would be sufficient to transmit the pencil of 140° air-angle, notwithstanding its greater expansion in the front lens. Thus it is obvious that the anterior refraction cannot account for the smaller openings of dry objectives in comparison with equal power immersion objectives of equal angular aperture.

The loss of amplification by the concave surface of admission is of course reduced to the fact that the hemisphere amplifies an object at the centre. We obtain the lens *b* (Fig. 68) with the concave front-surface by *cutting out* a hemisphere *a* of the same radius, and as this has previously amplified the object by *n* diameters, that amount of amplification is lost when it is taken away.

FIG. 68.



(c) *The Hemisphere as a Condenser.*

There is another phase of the hemisphere puzzle which we can vouch for as having very much puzzled some angular aperturists.

Comparing the case of an object on an ordinary plane slide (Fig. 69) turned with its under surface to the heavens, and another object on a slide with a portion of a sphere cemented on, the object being at the centre of the sphere (Fig. 70), it is said that the former object receives more light than the latter. The former receives light from the whole 180° of the heavens—that is, all the light from between the points *a* and *b*; the other object only receives light from between the points *c* and *d*, which is a less angular range than *a* and *b*. All rays from beyond *c* and *d* do not fall upon the sphere, and there-

FIG. 69.

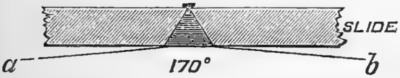
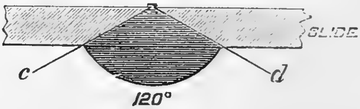


FIG. 70.



fore not reaching the object, there must be less illumination, unless the lens could be enlarged to a complete hemisphere.

This consideration, however, overlooks the fact that a hemisphere produces *concentration* (or condensation) of the light at its centre (which does not of course exist in the case of Fig. 69). Though rays which are directed to the centre are not refracted, the fact is, nevertheless, that the *same* rays which from any point (or small element) of the heavens reach a circle of definite diameter δ of the object in Fig. 69, are, by the action of the sphere, collected on a circle of smaller diameter $\frac{\delta}{n}$ in Fig. 70 (n being the refractive index of the lens), and consequently the original circle δ under the sphere receives from every point of the heavens, between c and d, n^2 times more light than an equal circle of the object on the plane slide. This may be proved by a similar dioptrical demonstration to that given above.

It is thus seen that the object, in the case of Fig. 70, may obtain the same light from a *portion* of the heavens as in Fig. 69 is obtained from the whole. If the angle between c and d should be 82°, the illumination of the object would be the same exactly. If that angle should be nearly 180° (in the case of a very large hemisphere and a very thin slide), the illumination in Fig. 70 would be n^2 times greater than in Fig. 69.

(2) Illumination Fallacies.—We have called these "illumination fallacies" for want of a better term, although that does not quite express their true character. We give the substance, however, as it has been put to us on many occasions with slight variations.

Assume the full apertures of a dry and an immersion objective to be illuminated from beneath the slide, so that we have a pencil above the slide of 170° in air in the first case, and 140° in oil in the second, the source of light remaining unaltered. Figs. 71 and 72 will then show the illumination which would be required to fill the apertures of the dry and immersion objectives respectively.

(a) When the angular aperturist recognizes that there is more light in Fig. 72, he then says that the conditions of the dry and immersion objectives are not the same, that the immersion objective

Fig. 71.

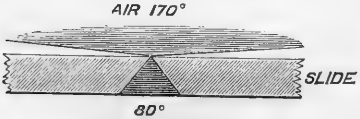
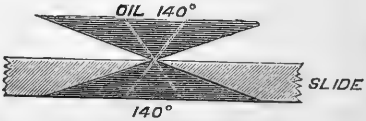


Fig. 72.



has been "allowed to get more light" than the dry objective. If it is only allowed to have a pencil of 80°, like the dry objective, its aperture will be found to be not greater but only equal.

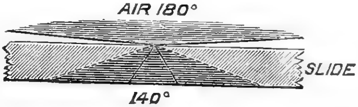
But if it is admitted that the illuminating pencil of 140° in Fig. 72 contains more light than that of 80° in Fig. 71, and that the former must be cut down to 80° also to establish equality, what becomes of the original argument? If the 140° in the glass of Fig. 72 is more than the 80° in the glass of Fig. 71, then the *upper* pencil of 140° in oil is more than the *upper* 170° in air. If the 80° in glass below is in both figures equivalent, then the 80° above in oil is equal to the 170° above in air as regards light, and not different, as first alleged.

(*b*) Or the angular aperturist will contend that as the immersion objective is illuminated by the pencil of 140° in the slide, the dry objective must be so also.

First consider the object as not adhering to the slide (see Fig. 73).

Then he points out that the dry object is at a disadvantage because all of the illuminating pencil outside 82° cannot get out, but is reflected back at the top surface of the slide.

Fig. 73.



This is of course a wholly inconsistent argument. The point he started with was that it was the *balsam* mounting of the object that prevented the full aperture of the dry lens being utilized—the light getting *out*; now it is the *dry* mounting that is in fault, and that prevents the light getting *in*.

Dealing with the point in another way, the object *does* receive an illuminating pencil of 180°, for that is the extension of the pencil which emerges from the slide. If, according to the angular aperturist, 180° of emission in air is the whole emission, 180° of admission into air is the whole also. If he denies that because it is only 82° in glass, then he admits that an incident cone greater than 82° in glass is more than an incident cone of 180° in air; this admits the principle of the unequal equivalent of equal angles in regard to the rays *incident* upon an object, and there is then no ground for denying it in regard to the *emitted* cones.

Secondly consider the object as adhering to the slide.

Then the object may receive the whole illuminating pencil of 140°. What is the result as to emission, however?

If the object is *transparent* (with a plane surface) no more light than that equal to the reduced pencil of 82° can be emitted into air, whilst the whole 140° can be emitted into oil; the hemisphere of radiation in air contains, therefore, less light than the hemisphere in oil.

If the object is *structural*, the law of diffraction and Fraunhofer's formula show that every incident ray yields several deflected rays, and that in the hemisphere of air there are fewer deflected rays than there are in the hemisphere of oil, i.e. that the whole of the rays emitted into oil is greater than the whole emitted into air. Cf. Figs. 108 and 109.

(*c*) Finally, the angular aperturist says that all he meant to convey was that the cover-glass of the balsam-mounted object prevented rays of light passing out into air, while when a suitable immersion fluid is used they can pass out freely by reason of the critical angle having been abolished.

Of course the whole question between dry and immersion objectives depends upon the critical angle; and equally of course, both parties admit that the air above the cover-glass in Fig. 62 stops rays from reaching the objective. But the crucial question is, of what "*whole*" is a portion stopped off? The angular aperturist contended, a portion of *that* "whole" which is emitted in *air* when the object is uncovered. In fact, however, it is of *that* "whole" which is emitted in *balsam*, and as the balsam "whole" is much greater than the air "whole" (a fact which he denied), the fractional portion of the former which is emitted is not necessarily less than the "whole" of the latter.

By all methods, therefore, we come back to the demonstration of the essential fallacy of the angular aperturist, viz. that equal angles in different media are the same.

(3) Power of the Plane Surface of a Lens.—Another fallacy is that the plane surface of the front lens of an objective exercises power, so that when in a homogeneous-immersion lens the action of this plane surface is abolished by the use of the immersion fluid, the back spherical surfaces have to be increased in power by way of compensation. Or, to put it in another way, that in dry objectives the refraction at the plane surface atones for less refraction at the spherical!

This fallacy so continually crops up when diagrams are attempted to be drawn to illustrate the possibility of a dry lens equalling a wide-angled immersion lens in aperture, and in various other forms in discussions on the difference between the two kinds of objectives, that we think it will be useful to dispose of it once for all.

Dealing with *experiment* first, there is a very simple way of demonstrating the fallacy experimentally.

Take a homogeneous-immersion lens. Here the spherical surfaces are *supposed* to have been increased in power to replace the action of the plane surface which has been abolished by the immersion fluid. If, then, there was *loss* of power when the plane surface was *abolished*, there must be *gain* of power when the plane surface is *restored*. Restore the plane surface, therefore, by using the objective on a dry-mounted object. According to the view propounded, the objective must now magnify more than it did on the balsam-mounted object. Let any one who believes in it try the experiment and record the result!

If *theory* is preferred to experiment, is it not obvious that a plane surface can have no power, the loss of which requires to be replaced by an increase of the power of the spherical surfaces?—that a plane surface is the optical zero as regards power (the hemisphere being the optical 1 or unit giving an amplification of an object at its centre in proportion only to the refractive index of the substance of which it is composed)? The refractive action of a plane surface affords change of divergence and of position of the focus, and in the case of wide-angled incident pencils introduces ample spherical aberration, but no power, so that the plane-front refraction can never be an element of power in a system, or compensate for loss of power anywhere else.

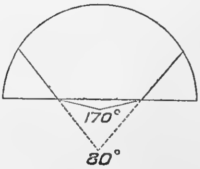
Again, as to the general dioptrical principle on which is based the distinction between "refraction with power," and "refraction without power." Amplification does not result from the unequal refraction of the rays coming from *one and the same object-point;* it depends solely on the unequal refraction of similar rays from *different object-points* (by similar rays being understood those which depart from different object-points in similar directions, i. e. parallel), and is therefore confined essentially to *curved* surfaces.

There may therefore be any large refraction of the *pencils* emitted from an object, but nevertheless no amplification, if parallel rays of any two different pencils should undergo the same refraction. This is the case of the plane surface. On the other hand, there may be no refraction of the *pencils* (the divergence of every pencil and the plane of the radiant may remain unchanged), but notwithstanding there may be any amount of amplification, provided parallel rays from two different object-points undergo unequal refraction. This is the case of a spherical surface in regard to an object situated at the plane of the centre of the sphere. Though in this case the divergence of the pencils and the plane of the focus is not changed by the refraction of the rays, there is an amplification of the object (as we have seen in the ratio of 1 : *n*), because there is an unequal refraction of any two parallel rays from different points of the object.

Once more, what can the angle of the incident pencil have to do with power? If any lens or lens surface can refract a given pencil of, say, 82° to a conjugate focus with any given amplification (say, two diameters), the same lens, i. e. the same curvature in the same position, will bring any larger pencil (140°) to the same conjugate focus with the same amplification. No increase in the power of the spherical surface is required, but only greater diameter of the lens to admit the larger cone.

The front surface of a dry objective has, of course, the effect of reducing an incident pencil in air of 180° to a pencil of 82° in glass, but without contributing to the power of the objective. As is shown by Fig. 74, the *same pencil* which in air is emitted under an angle of 170° is emitted in oil under an angle of 80°, and thus does not require the reducing effect of a plane refracting surface, and therefore no compensation is necessary for the absence of such a refraction. The rays are in such case identical before they reach the spherical surface, which cannot therefore require any alteration.

FIG. 74.



(4) **The Diagram Fallacy** (*The Stokes Immersion and the Shadbolt Dry Objectives*).—The diagrams drawn by Mr. Shadbolt in support

of his contention that an immersion objective cannot have a larger aperture than a dry one, have, as is known, been frequently drawn before and their fallacy as often exposed, though, as the diagrams have been ultimately withdrawn by their authors, the exposition has not hitherto appeared in print. We now, however, give it.

Mr. Shadbolt's assumptions were as follows:—

He supposed a *homogeneous-immersion objective* with a front an exact hemisphere as suggested by Professor Stokes (see Fig. 75) which admits from Q a pencil of 113° balsam-angle and transmits it to the back combination as a pencil from *q* of 66°.

FIG. 75.

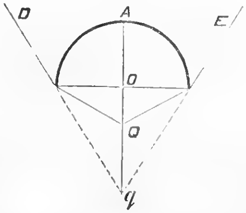
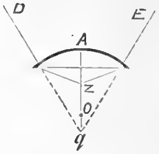


FIG. 76.



With this he compared a *dry objective* with a front lens of the same curvature as the immersion front, but of *less thickness* (as in Fig. 76). The position of the front in regard to the radiant was so arranged that a pencil from *q* of 66° is transmitted to the back combination as before. This pencil, however, emanates from a radiant *z* in air, and is of larger angle than the 113° which was the limit of the Stokes objective, so that it was supposed and contended that the latter had been changed into a dry objective of larger aperture! *

The application of one of the simplest and most elementary optical considerations shows at a glance that the demonstration is an entire mistake, and it well illustrates how deceptive geometrical diagrams of aperture may in reality be if they are drawn without a clear appreciation of the optical principles applicable to the subject.

There are two methods of demonstrating the fallacy, the one the *strict* and the other the *simple* method. We deal with the former first.

(a) *The Strict Method.*

With the same set of posterior lenses (of any given composition) the Stokes front would give an immersion objective of 112° 20′ crown-glass angle, and the Shadbolt front a dry objective of 125° 40′ air-angle under the conditions laid down in his paper, viz. that the emergent pencil with the virtual focus *q* is in both cases 66°.

Compare now the performance of these systems as to the ampli-

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* The Shadbolt lens as it stands is not, of course, a practical construction, though the Stokes lens is. It could, however, be utilized by adding a duplex front to correct the spherical aberration. We have not done this, as it seemed that it might give rise to the supposition (though it would not be really the case) that we had altered the conditions laid down. We therefore simply note the fact.

fication which is obtained with them, beginning with the amplification of both fronts.

According to the law of aplanatic convergence referred to at page 321, if O and O* are any two conjugate aplanatic foci (it matters not whether O* is a real or a virtual focus), u and u^* the semi-angles of divergence of the pencils from these foci, N the linear amplification of the image at O*, and n and n^* the refractive indices of the medium in front and at the back of the system; then

$$\frac{n \sin u}{n^* \sin u^*} = \mathrm{N}.$$

Applying this formula to the two front lenses, n^* is $= 1$ for both (there being air at the back), but n is $= 1 \cdot 525$ for the Stokes front, and $= 1$ for the Shadbolt front. Therefore, the linear amplification of the former (for the conjugate foci Q, q) is

$$\mathrm{N} = \frac{1 \cdot 525 \times \sin 56^\circ\ 10'\ (u)}{1 \times \sin 33^\circ\ 0'\ (u^*)} = (1 \cdot 525)^2 = 2 \cdot 33;$$

and of the latter (for the conjugate foci z, q)

$$\mathrm{N}' = \frac{1 \times \sin 62^\circ\ 50'\ (u)}{1 \times \sin 33^\circ\ 0'\ (u^*)} = 1 \cdot 63.$$

Let M be the linear amplification (whatever it may be) of the posterior system which is common to both objectives, then the total amplification of the Stokes objective (S) will be M.N, and of the Shadbolt objective (Sh) M.N′, which is less by $\frac{\mathrm{N}}{\mathrm{N}'} = 1 \cdot 42$, i. e. in the proportion of 5 : 7 approximately. Therefore, the focal length of the objective Sh must be greater than that of S in the same proportion, so that Sh is a *lower power with the same back combination.*

It has already been shown (p. 308) that, if a lower power objective utilizes only the *same* back lens as a higher power, it will not have the same, but a *lower aperture.* This must also be obvious instinctively, for if it were not so, opticians would of course make their $\frac{1}{4}$-inch of 120° aperture with the same *small* back lenses as are sufficient for the $\frac{1}{8}$-inch of 120° aperture!

Therefore, Mr. Shadbolt, claiming to have suggested a way to obtain the pencil from q with 66° divergence from air *without loss of aperture,* has in fact done so by a method which necessitates a loss of amplification, and therefore loss of aperture! In all cases of diagrams such as these, it is not sufficient to look only at the diagram on paper; it is essential to put the question, "Have we still the same system?"—i. e. the same power.

It may be said, however, that Mr. Shadbolt's suggestion was only given as an example, and that if it is insufficient another construction can certainly be devised for catching the pencil q with 66° angle from air, and without loss of aperture. Now, "without loss of aperture" can, under the conditions of the whole argument (the back combination remaining unaltered), mean nothing else than "without loss of amplification" in the action of the front. Therefore, if it is possible by any other means to catch the pencil *from air* without loss of aperture, a lens or any combination of lenses must exist which is capable of collecting rays from a focus Q in air to a focus q in air, so that the angle $u^* = 33°$, and the amplification N at $q = 2\cdot 33$, as in the Stokes front. The above formula would then be

$$\frac{1 \times \sin u}{1 \times \sin 33° \, (u^*)} = 2\cdot 33,$$

which would require an angle u for which

$$\sin u = 2\cdot 33 \times 0\cdot 545 = 1\cdot 26,$$

that is, a sine greater than 1 !

The widest pencil which can be got out of a dry front under an amplification of $2\cdot 33$ is defined by the condition

$$\frac{1 \times \sin 90°}{1 \times \sin u^*} = 2\cdot 33, \text{ or } u^* = 25° \, 30', \text{ i. e. } 51° \text{ instead of } 66°.$$

Thus it is proved that the Stokes immersion-objective has a larger aperture than any dry objective with the same back combination can have. The same pencil (66°) which is readily got out of the immersion front into the back combination can*not* be got into it from *air*, except with loss of amplification, i. e. of aperture.

This disposes of the argument on the basis of Professor Stokes' diagram.

It does not prove, however, that *no* dry objective can have so large an aperture as can be got with an immersion lens ; it only proves that this is not possible with a dry objective under the assumption of the same back combination. On page 321 will be found the demonstration which proves that, as a *general proposition* applicable to all cases and apart from all questions of particular constructions, a dry (Shadbolt) objective can never equal in aperture an immersion (Stokes) objective of wide angle.

(b) *The Simple Method.*

But Mr. Shadbolt may say that his mistake must have been a very excusable one if the proof requires formulæ which are not to be found in English books, and we will therefore show how by the application of the most elementary principle to be found in English optical books, and without any calculation, the fallacy may be demonstrated.

The loss of amplification with the Shadbolt front is obvious at a glance, for the refraction at the spherical surface has been *diminished.*

A spherical surface (of refractive index n) amplifies an object which is within the medium (for instance, the *virtual* object obtained from the *real* object below a plane front surface) according as the distance of such object from the vertex is increased. If the radiant coincides with the centre the linear amplification will have a given value ;† but if the radiant is withdrawn from the centre to a point more distant from the vertex the radiant of the emergent pencil is withdrawn still more. The emergent pencil is reduced in divergence and, all other circumstances remaining the same, this necessarily indicates *increased* amplification.

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† It will in fact be n, see *ante*, p. 327.

Thus *withdrawing* the radiant from the vertex of the sphere is *increase* of amplification by the spherical surface, and *approaching* the radiant is *loss* of amplification—propositions the truth of which may be very readily tested by an ordinary plano-convex lens.

Now in the Shadbolt front *the radiant has been brought nearer to the vertex!* and there is therefore loss of amplification (cf. Figs. 75 and 76).

This approximation is moreover a necessity, for Mr. Shadbolt so far rightly saw that his emergent pencil of 66° could not be so much increased within the glass as it is in the Stokes front. In the latter (considering the pencil from above downwards) the 66° can be increased to 113° as there is no plane surface of exit bounded by air. In the dry objective, however, there is such a surface, and nothing beyond 82° can emerge, so that instead of being able to increase the pencil from 66° to 113° it can only be increased to 82°, that is, the refraction at the spherical surface must be diminished in order to have within the glass a pencil not exceeding 82°.

The notion that the refraction which is introduced by the lens at the plane front surface can compensate for this loss at the spherical, is one of the strangest of the aperture fallacies, as has been shown in the preceding note.

In this simple mode the fundamental mistake of Mr. Shadbolt's diagram is shown.

(5) **Fallacies in Practical Construction.**—It need hardly be pointed out that the better practical optician will, *cæteris paribus*, be he who is the best grounded in those theoretical principles which lie at the root of the construction of objectives. The mistakes into which the practical optician who is an angular aperturist is led, may be shown by several instances:

(1) We will take first the case of the construction of objectives of high angles. An optician holding the views we have referred to, will have observed that when he increased the angular aperture of his objective from 100° to 120° he obtained a substantially increased effect. He is therefore encouraged to improve the construction and add yet another 20°, making 140°, or a third 20°, making 160°, and yet more until he arrives at the nearest approximation to 180°, all the time supposing that with each additional 20° he had obtained the same increase of effect as at first.

The knowledge that aperture must be measured by the *sines* and not by the *degrees* would, however, have shown him that the increasing effect was not properly indicated by the figures 100, 120, 140, 160, and 180, but by 77, 87, 94, 99, and 100; so that the real increase is not by additions of 20, but of 10, 7, 5, and 1 only. He would see, therefore, that the difference between 140° and 180° was so slight—being only 6 per cent.—as not to make it worth his while to encounter the difficulties of technical construction attendant upon the extreme increase of angle.

(2) If the practical optician considers that *aperture* and *angle* are identical, the same angle being always the same aperture whether in a dry or an immersion objective, he will continue to struggle for the optical *perpetuum mobile*—to construct dry systems which shall equal

in performance the best immersion glasses, which would undoubtedly be a great triumph, inasmuch as dry objectives are so much more convenient to use than immersion. Why should not this be possible, he thinks, with skill and patience, if the question depends simply on the angle of the admitted pencil!

(3) If, again, he should hold one of the views of the effect of increased angle which we have above referred to (p. 319), viz. that it is a defect, he will confine himself to the construction of objectives of low angle, which he contends must in all cases exhibit objects better than those of large angle. With the large angle there is greater all-round vision, as if many eyes were looking at the object at the same time, and hence the resultant effect must, he thinks, be general indistinctness and imperfection in the image. Yet objectives of the highest angles hitherto constructed are easily proved to give images of sufficiently thin preparations without confusion.

(4) Several other practical mistakes flow from the same erroneous theoretical assumptions, one of the most important of which we deal with under a separate head, "Not Image-forming Rays."

(6) "Not Image-forming Rays."—This represents a very curious form of the angular fallacy.

At the commencement of the old aperture controversy, it was asserted that no objective could be constructed, whether dry or immersion, which would allow of an angle in excess of 82° in the body of the front lens. In the same way as Nature abhorred a vacuum, she was supposed to abhor an objective which could act in such defiance of established laws of critical angles and otherwise!

At the time that this view was first enunciated, no such objectives had in fact been constructed, so that the statement was then partially excusable. The first claim to have constructed such an objective was received with great derision, and it required some years to finally establish what is, however, *now* universally accepted as a fact, that immersion objectives *do* allow of an angle in excess of 82° in the front lens.

The germ of the original fallacy still persists, however, in the contention that although the surplus rays in excess of the 82° do really exist, yet that they are *not image-forming rays.*

Now as the limit of 82° is simply double the critical angle between *air* and glass, it can have no possible application whatever to the case of rays passing, not from air, but from *water* or *oil* to glass, and it must be clear therefore on theory that this notion is a fallacy.

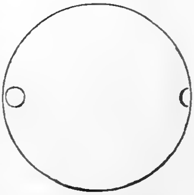
It is obviously for those who contend that the rays (even when passing from oil to glass, and without any air-film!) cease to be image-forming rays at 82°, to show on what grounds they base their contention; but we will nevertheless point out one or two experiments which—apart from any reference to the obvious theoretical considerations—show the *effective* action of the surplus marginal rays with wide-angled immersion objectives. It is hardly necessary to point out that for these experiments it is essential to use objectives which are properly corrected for *all* zones, marginal as well as central. There are plenty of such objectives in existence, though it is not unnatural that the belief that the surplus rays passing through the marginal zones are not image-forming rays, should lead the optician to concentrate his attention on the central corrections to the comparative neglect of the marginal. Any experiments with *such* objectives will, of course, be useless.

The simplest experiment of all is to take a homogeneous-immersion objective of large aperture, say 1·25, and put a stop (of cardboard or tin-foil) on the back lens, leaving only a small clear annulus of the extreme marginal rays. With sufficient obliquity of the illumination the image of the object will be seen perfectly delineated either on a dark or bright field.

Another experiment is to take a similar objective and focus it to any rather coarse object with sharp outlines (say lines ruled in a thin silver film on a cover-glass and balsam mounting) and illuminate by a narrow pencil from an immersion condenser such as a hemisphere, so as to be able to get at pleasure a very oblique pencil. If the illumination is changed from central to very oblique until the field begins to darken, a well-defined image of the outlines will be seen with slightly coloured borders only. If the illuminating apparatus admits of a rapid change of the incidence without any alteration of the object, it can be established that the image with the oblique beam is obtained at *the same focus* of the eye-piece, and that no change of adjustment is required for distinct vision. Looking down the tube when the eye-piece is removed, the oblique pencil will be seen emerging close to the margin of the clear aperture of the objective. Thus the marginal zone transmits image-forming rays.

Or focus the objective on a good specimen of *Amphipleura pellucida* and use sufficiently oblique illumination for seeing the lines clearly. On removing the eye-piece, placing the pupil on the air-image of the diatom and looking down on the lens, the direct incident beam will be seen emerging as a bright spot and exactly opposite and *close to the margin* a faint bluish light (a portion of the first spectral beam) —see Fig. 77. If now a small piece of paper is placed on the back lens of the objective so as to just cover up the blue light, and the eye-piece is replaced, the diatom is still visible, but all the striation which was imaged by the blue marginal light has entirely disappeared. The latter must therefore consist of image-forming rays.

FIG. 77.



Other instances may be shown by using the vertical illuminator, in the manner suggested by Mr. Stephenson,* in which case, when transparent objects are used, the light within 82° passes through, and is not brought to the eye. The image is therefore seen by the marginal rays.

Indeed, the experiments which show the absurdity of the notion

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* See this Journal, ii. (1879) p. 266.

that the marginal rays are not image-forming may be almost infinitely varied.

If these experiments cannot be made to bring out the desired results, one thing is evident, the objectives that have been made use of have not been properly corrected!

(7) "**Only a Question of Nomenclature.**"—The last fallacy of the angular aperturist, after he feels that his view is not so sound as he supposed, is that the dispute has been "only a question of nomenclature."

Now we quite agree that in scientific discussions generosity to fallen foes is no more out of place than it is in actual warfare, but, nevertheless, we have always combatted this remark, because we have had impressed upon us by the force of considerable practical experience that it has in the past largely contributed to obscure the fact, which it is essential should be borne in mind, that the difference in the two views is in reality one of the highest importance, and one which every person who works with the Microscope should appreciate. The biologist and even the microscopist sees the controversy on aperture end in the suggestion that it is "only a question of nomenclature," and he therefore comes to the conclusion that the whole matter is one of perfect indifference as regards the practical use and improvement of the Microscope. If English microscopists had only been able to grasp the theoretical grounds on which wide-angled immersion lenses are shown to have necessarily a larger aperture than dry ones, there can be no doubt that we in England would have been ten years ago where we are only to-day.

"Only a question of nomenclature" is a phrase which has a well-defined meaning, being applied to the case of discussions in which there is agreement as to the *essence* of the thing which forms the subject of discussion, the difference being only as to what it should be *called.*

Let us consider then whether the differences on which the aperture theories are founded do or do not go to the essence of the matter, and in this we will draw exclusively from the printed pages of the recent discussion. We confine ourselves to a few only, but we need hardly point out that an exhaustive consideration would of course simply be a summary of the whole of the fallacies to the exposure of which the preceding pages have been devoted.

(1) It was asserted and made the keystone of the demonstration that the radiation of light in air was exactly the same as radiation in water or oil, and that equal angles in different media represented equal apertures. If that is only a question of nomenclature there can never be a dispute on essentials.

(2) To support the view contended for, it is supposed that the plane surface of a lens exercises power, and that when that is abolished there is a loss, which must be compensated for by increased curvature at the spherical surfaces. This is a notion which not only upsets all the principles of practical optical construction, but the most settled—indeed, the simplest—laws of optics. Can it be said that this is only a dispute over nomenclature?

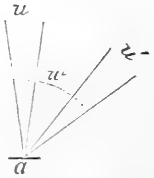
(3) *A dry objective of* 180° *angle, working on dry objects, is assumed to represent the maximum of microscopical perfection as regards aperture which can never therefore be surpassed by an immersion objective.*

Will any one seriously maintain that a dispute on *this* point is only one of nomenclature—that it is only a question of nomenclature to contend that immersion objectives present only incidental and comparatively unimportant advantages over dry objectives, except in the single case of the latter being used on balsam-mounted objects, and to deny to them the quality which raises them, in regard to aperture, above anything to which the most perfect dry objective can ever attain? a quality, moreover, which is not a merely abstract optical consideration, but is in fact an essentially *practical* one in regard to the performance of the Microscope upon the most minute objects.

III. Photometrical Questions connected with Aperture.

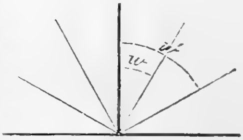
(1) Difference of Radiation in the same Medium. — The Lambert law shows that the quantity of light emitted by any infinitesimal surface-element (or "bright point") varies with the obliquity of the direction of emission, being greater in a perpendicular than in an oblique direction. The rays are less intense in proportion as they are more inclined to the surface which emits them.

FIG. 78.



If *a* (Fig. 78) is a radiant element emitting light within a small cone *u* (of angle *q*) in a perpendicular direction, and also within an *equal* cone *u'* in an oblique direction, the angle of obliquity between the two being *w*, then the quantity of light emitted by the element *a* in the oblique direction, and contained within the cone *u'*, is *less* than that which it emits in the perpendicular direction and contained within the cone *u*, though the cones are of equal extent (q). The relative quantities of light in the two cones are as $q : q \cos w$; so that a pencil varies according as it is taken close to or removed from the perpendicular.

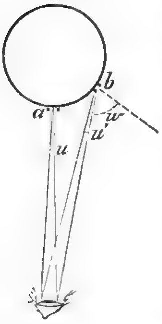
FIG. 79.



Owing to the different emission in different directions, therefore, the quantities of light emitted by one and the same element in one and the same medium, by cones of *different* angle (*w* and *w'*, Fig. 79) are *not* in the ratio of the solid cones, as would be the case with equal emission in all directions, but in the ratios of the squares of the sines; so that the squares of the sines of the semi-angles constitute the true measure of any solid pencil of rays.

The simplest experimental proof of the unequal emission in different directions will be found in the fact that the sun, or the moon, or any similar bright spherical object, with so-called uniform radiation in all directions, is seen projected as a surface of *equal* brightness.

Fig. 80.



If there were equal intensity of emission in all directions, what would be the necessary result? Compare two equal portions of the surface, one *a* (Fig. 80) perpendicular to the line of vision, and the other *b* greatly inclined. Every infinitesimal surface-element of *b* sends to the pupil of the eye a cone of the same angle *u'* as a similar point of *a* (the slight difference of the distance from the eye being disregarded). If the intensity of the rays were equal, as supposed, the whole area *b* would send to the eye the *same* quantity of light as the equal area *a*, since both areas contain exactly the same number of elements. But the *whole* quantity of light from *b* would be projected upon a smaller area of the retina than that from *a* (as *b* appears under a smaller visual angle, being diminished according to the obliquity, or as 1 : cos *w*). Consequently, if the assumption were true, *b* must appear to be brighter than *a*, and the sphere would show increasing brightness from the centre to the circumference. Close to the margin the increase ought to be very rapid, and the brightness a large multiple of that at the centre.

This, as is well known, is not the case—the projection of the sphere showing equal brightness. The quantity of light, therefore, emitted from *b* within a given small solid cone *u'* in an oblique direction, must be *less* than that which is emitted from *a* within an equal solid cone *u* in a perpendicular direction; and the intensity of the rays must decrease in the proportion of 1 : cos *w* when the obliquity *w* increases.

Therefore Fig. 81 is not a correct diagram of the rays emanating from a surface-element, but Fig. 82—the density of the rays decreasing continuously from the vertical.* (Cf. also Figs. 59 and 60.)

Fig. 81.

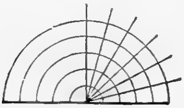
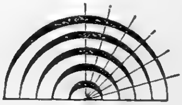


Fig. 82.



This subject bears also upon the question of the loss of light with dry objectives. It was seen that immersion objectives gave a great increase of light over dry objectives. As the true explanation of this was not appreciated, it became necessary to account for the increase otherwise, and the reflection at the plane face of the lens was taken to be the reason. A large amount of loss is supposed to be accounted for by the following reasoning:—A pencil of light is assumed to be properly shown in Fig. 81, the density of the rays being uniform, whether they are close to or removed from the perpendicular. If this pencil

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* The thickened lines indicate the greater amplitudes.

is supposed to be divided into, say, three equal parts around the perpendicular, the loss of light by reflection in the second third, where the rays are more oblique than in the central one, is assumed to be much greater than in the latter, and the loss in the outer third, where the rays are yet more oblique, as much greater still; so that a total average loss is made out to exist of not far short of 50 per cent.

The consideration is so far sound in that it proceeds on the assumption that the loss of light by reflection increases with the increasing obliquity of the rays. The mistake, however, is in supposing that Fig. 81 is a correct representation of the pencils instead of Fig. 82. In the calculation of the 50 per cent., therefore, the fact was overlooked that while with increasing obliquity there is greater loss by reflection, yet there is at the same time *less light to lose.*

There is of course loss of light with a dry front, which is nearly all avoided in the case of the immersion, and is so far a practical benefit. This benefit, however, is very subordinate in comparison with the great increase of light which is due to the greater photometrical equivalent of equal cones in denser media, an immersion objective of 120° balsam-angle being capable of admitting more light in the ratio of 9 : 4 than a dry lens of equal air-angle.

(2) **Increase of Radiation in Glass, Oil, &c.**—The angular-aperture theory, as we have already seen, is sometimes rested (though improperly) entirely upon the question of quantity of light, and involving the assumption that equal angles in air and balsam contain the same amount, so that a smaller angle in balsam must contain less than a larger air-angle. The notion that a balsam-angle of 100° can contain more light than an air-angle of 180°, a given fixed illumination being supposed, is regarded as an absurdity.

The fact of an increase in radiation with the increase in the refractive index of the medium into which the emission takes place has been established for many years, the case of immersion objectives being hitherto the main (if not the first) practical application of it. The principle may be proved theoretically and experimentally.

Those who are interested in the *theoretical* consideration will find it fully developed by Professor R. Clausius in his celebrated paper "On the Concentration of Calorific and Luminous Rays."* Later, a similar principle was shown by Professor Helmholtz (in his paper "On the Limits of the Power of the Microscope") to be a direct deduction from that of conservation of energy. The former paper was an outcome of researches which were induced by previous researches of Sir W. Thomson and Professor Rankine.

For the *experimental* consideration, the apparatus which we exhibited at the March meeting, and for which we are indebted to Professor Abbe, will be found useful for showing the different *photometrical* equivalent of equal angles in different media.

The apparatus (see Figs. 83, 84, 85) consists of a very thin plate of polished porcelain A, which (for support) is cemented with balsam to a disk of ordinary glass *a*. A block of crown glass G is also cemented with balsam to the polished surface of the plate A. A

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* Poggendorff's Annalen, cxxi. (1864).

second plate B *b*, exactly similar to A *a*, is laid on the anterior surface of the glass block G. The whole is mounted in a brass box, for convenient manipulation, and for limiting a given portion f_2 of the anterior porcelain plate A, exactly equal in size to the sectional surface f_1 of the glass block. The plates A and B are ground down to such a thinness that they are just non-transparent for *direct* rays, but give a strong *diffused* illumination, radiating very uniformly in all directions.

Fig. 83.

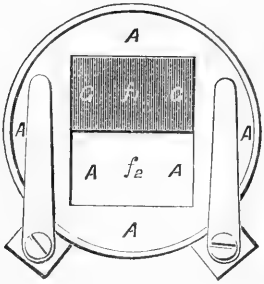


Fig. 84.

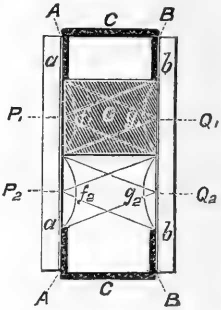
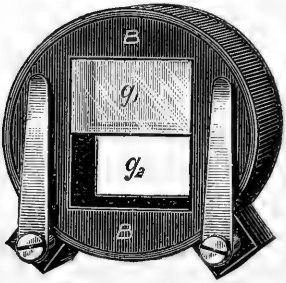


Fig. 85.



If now the apparatus is directed to the sky, or held close to a gas-flame (the plate B being turned towards the observer and shaded from any incident light*), *one* of the fields g_1 or g_2, opposite to f_1 or f_2, will appear *decidedly and considerably brighter* than the other.

At the March meeting this fact was at once triumphantly accounted for by an angular aperturist. "The light passing through "the air space is unimpeded and unabsorbed, and therefore illuminates "that part of the plate B which is opposite to it more strongly. In "passing through the glass block, however, it is absorbed, and so "shows a feebler illumination." On removing the plate B, however, it was seen that it was the field g_2 opposite to f_2, and with the *air-space* intervening, that had the *feebler* illumination, as if the light had passed through a fog; whilst f_1, where the light had passed through the glass block, gave the greater illumination!

What does this experiment show? As the two fields, f_1 and f_2

* In Fig. 85 both of the plates A and B are supposed to be removed.

of the plate A are close to one another and are of equal size, the same quantity of light (very approximately) will be incident upon them; and as the plate A is of porcelain and polished, neither the internal constitution nor the surface undergoes any change by the cement connecting it with the glass block. Thus the two fields f_1 and f_2 are under equal conditions, with the difference, however, that f_1 emits rays into balsam and crown glass, and f_2 into air.

The plate B, which is only laid on the glass block, receives all the light which has been emitted *into balsam* from f_1 upon the opposite surface g_1 of the glass block, and all which has been emitted from f_2 *into air* and upon the field g_2. As the former field is brighter than the latter, the quantity of light emitted in the one case must necessarily be greater than in the other, and the more so since the absorption of light is certainly greater in the glass block.

Owing to the identity of all geometrical conditions, it is obvious that every point P_1 of the surface f_1 throws upon the field g_1 the same solid cone of rays as the corresponding point P_2 of f_2 throws on g_2, and that every point Q_1 of the field g_1 *receives* an equal cone to the corresponding point Q_2 of the field g_2. Consequently, the intensity of emission in balsam must be greater than the intensity of emission in air, whilst the illumination of the object and all other circumstances are the same. A similar difference of emission must take place in all directions round the points P_1 and P_2; and thus the whole of the emission in balsam (i. e. the quantity of light conveyed from every unit of surface within the whole hemisphere) is seen to be greater than the whole in air, a given fixed illumination being supposed.†

The idea of an unequal photometrical equivalent of equal pencils in different media may be developed by some simple experiments, which also show how absurd is the notion that there is a loss of aperture (or of light apart from mere partial reflection) when a dry objective is applied to a balsam-mounted object.

(1) Any object O in air (Fig. 86) will send into the pupil a pencil of a given angle u^* from every point, and is seen (with any given fixed illumination) with a certain brightness.‡

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† This does not, of course, imply the assertion that the *whole* of emission from such a porcelain plate, or any other object with diffused radiation, would *increase continually* as the refractive index of the surrounding medium is increased, which would lead to the absurd inference that such an object could give out more light than is incident upon it! If the index of the medium should exceed the refractive index of the object, the radiation (whether of reflected or transmitted light) no longer embraces the whole hemisphere, but breaks off at a given obliquity. This is shown from the consideration that the emission of light is not confined to the mathematical surface of the object, but arises from a layer of finite (though very small) depth. Thus, the *total* amount of reflected or transmitted rays from an object reaches a maximum with a given density of the surrounding medium, though the emission within any narrow cone (as long as there *is* emission still) will always increase with increasing density.

‡ If the distance is increased and the angle u^* diminished, the *area* of the retina which is affected by the rays from a given area of the object is of course diminished as the square of the distance, i. e. in the same ratio as the number of the rays from every point is diminished. Every sq. mm. of the retina receives, therefore, the same quantity of light at all distances, and the object, therefore, always appears of the same *brightness.*

(2) An identical object O (Fig. 87) *cemented to the under surface of a glass plate*, will appear at a somewhat higher plane O*, but neither amplified nor reduced. The pencil *u*, however, which is gathered in from the radiating object, is less in angle than *u** in the ratio approximately of 1 : 1·5; and if, therefore, equal pencils in air and in glass were equivalent the quantity of light emitted from any square millimetre of the object and received by the pupil would be less in the proportion of $1 : (1 \cdot 5)^2 = 1 : 2 \cdot 25$. The object would therefore be seen *less bright* in the same proportion.

Fig. 87.

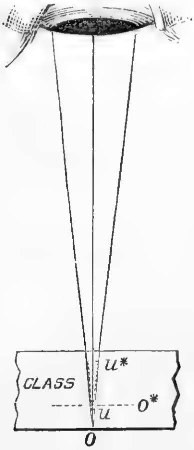


Fig. 86.

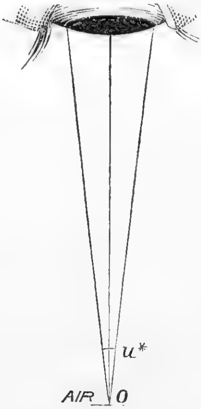
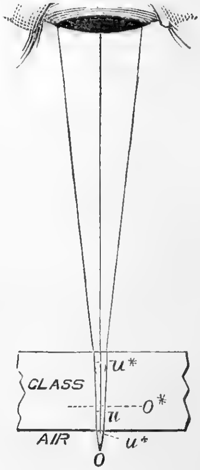


Fig. 88.



(3) The same object, separated by air from the under surface of the plate, would emit once more pencils of the aperture *u** (Fig. 88). The circumstances will be the same as in (86). As the loss of light at a polished glass surface with perpendicular incidence is not more than about 6–7 per cent., this case, 88 (if the hypothesis were correct) would show the object *brighter* than (87) at least in the proportion of 2 : 1. Any one may satisfy himself at once that this is *not* the case, and that the difference in brightness between (88) and (87) is not appreciable. Therefore the smaller pencil *u in glass* must contain as much light as the wider pencil *u** *in air*.

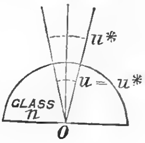
If instead of the eye a microscope objective (dry) which takes in any wide pencil—say 140°—is used, the above considerations must equally apply; if $u^* = 140°, u = 2 \times 38° 50' = 77° 40'$ (n being 1·5). The second case (87) would be that of an object cemented to the under surface of the covering-glass. The third case (88) would be that of an identical object with the cover-glass laid on only. If 140° in glass were the same as 140° in air, the 77° 40′ in glass would be very much less, and as the quantities of light must be estimated by the squares of the sines, there would of course result a *very great difference* of brightness in passing from (87) to (88), so great that at any rate it cannot be accounted for by the loss of light from *one* reflecting surface *more.*

The experiments must of course be made with illumination from *below* in order to secure equal illumination in the three cases, and with objects which are not altered by immersion in balsam or oil.

More striking still is the result of the following consideration. Suppose an exact hemisphere of glass ($n = 1 \cdot 5$) and an object close to its centre and under the conditions of (87) (Fig. 89).

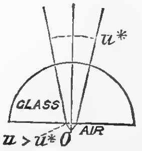
The object adhering to the glass is seen by the naked eye or by a Microscope at the same plane at which it actually is, and with the *same brightness* as when in air (see Fig. 86) (the slight loss by absorption and reflection not considered). It is, however, amplified in the ratio of $1 : n$.

FIG. 89.



Apart from any consideration of the *cause* of this amplification, the question necessarily arises, how is it possible that *equal* pencils (i. e. of the same angle), the one in air (86) and the other in glass (89), give the same brightness while in air (86) every square millimetre of the object continues to be the same square millimetre, and in (89) every square millimetre of the object is *enlarged* to $n^2 \times$ sq. mm. The total quantity of light which is obtained from every square millimetre of the object is obviously n^2 times *more* in (89) than in (86). There can be no other answer than this: pencils of equal angle, the one emitted in air and the other in glass, are *different* things *physically*, though they are *equal geometrically*—the pencil in glass contains $n^2 \times$ the light of the pencil in air. This conclusion is shown to be correct by comparing (89) with Fig. 90, where the object is in air but close to the plane surface (as in 88). Here the pencil from the object, in order to yield the same emergent pencil u^*, must have an angle u in air, which is greater than u in (89) according to the law of refraction. Nevertheless this greater cone of the emitted rays brings out the same brightness of image as in (89) under the same amplification.

FIG. 90.



IV. Microscopical Vision and the Delineating Power of Objectives.

The consideration of aperture involves two distinct questions: *First,* Can immersion objectives have any and what excess of aperture over the maximum attainable by dry objectives? and *secondly,* What is the function of increased aperture?

Up to this point we have been occupied exclusively with the first question (to which, in accordance with the practice hitherto in vogue, we have given priority) the angular aperture theory insisting that a dry objective of 180° air-angle represents the maximum aperture possible. The mistake of this view and the establishment of the true view may, as it has been seen, be demonstrated upon those ordinary dioptrical principles, with none of which can, or in fact does, the angular aperturist venture to disagree. His mistake has not been based on any ignorance of those principles, but has simply arisen from a deep-rooted disinclination to modify former views—a disinclination which, not for the first time in the history of science, has led those who are beset by it to deny the plainest facts long after their truth has been established.

Leaving now the consideration of the increased aperture of wide-angled immersion objectives over dry objectives, we propose to deal with the second question (which represents a problem that long perplexed the minds of microscopists), *On what principle does the advantage derived from increased aperture depend?* That an increase in the aperture of objectives is accompanied by an increase in their performance has been established since the date of Dr. Goring's discovery of the fact, and the true explanation, whatever it may be, is of course independent of any consideration of apertures in excess of 180° angular in air or even of immersion objectives at all. The question arises when we consider only *dry* objectives.

Down to so late as 1870 all endeavours to give an answer to this question had entirely failed. One of the ablest and most elaborate of these attempts is that contained in the article "Angular Aperture" in the 'Micrographic Dictionary,' but apart from the fact that it starts with the fallacious assumption that the essential condition of increased aperture is increased obliquity of the rays to the object, no one can ever have risen from a perusal of that article, who was really desirous of understanding the subject, without feeling the unsatisfying character of the explanation attempted. That the true explanation was still wanting was evident from the remarkable way in which all microscopical authors avoided the subject, never getting beyond the bare statement of fact that increased aperture in some way involves increased resolving power. More than one microscopist devoted great pains and labour to the endeavour to establish a consistent theory, but all failed in consequence of having continued to consider microscopical vision as essentially the same in principle as vision with the naked eye, and so applying to the question only *dioptrical* considerations.

The crucial question which any explanation of the virtue of increased aperture must face is the following, which on the old view must necessarily be an insoluble paradox. How is it that we obtain a greater effect by the increased obliquity of the incident illuminating beam *to the axis of the Microscope*, even although at the same time its obliquity *to the object* is decreased? The ordinary explanation of shadow and similar effects obviously fails here.

(1) The Abbe Theory of Microscopical Vision.

The solution of all the mystery was at last discovered by approaching the matter from a different point of view, and recognizing what is now obvious, that in the case of the objects of minute size with which the Microscope deals, and for the vision of which aperture is necessary, the conditions of ordinary vision do not apply.

When we consider waves of sound it is a well-recognized fact that to produce an acoustic shadow the obstacle must be many times greater than the length of the sound-waves. If the obstacle is reduced in size the waves pass completely round it, and there is no shadow, or if the notes are of higher pitch so that the waves are reduced in size a smaller obstacle than before will produce the shadow. In the case of light, when the objects are large in comparison with the wave-lengths, shadow effects, of course, result, that is, we have a rectilinear propagation of the light; but when they are reduced to smaller and smaller dimensions they are not now many multiples but only a few multiples of the wave-lengths, and we have no longer rectilinear propagation,--*dioptrical* considerations are not therefore applicable, and we have to refer to the laws of *diffraction*, i. e. those laws which explain the changes produced in the rays of light in consequence of their interception or unequal retardation by minute particles. In now explaining microscopical vision, it is necessary, therefore, to take into account that the images of objects in the Microscope are not formed, as was formerly supposed, exclusively on the ordinary dioptric method (that is, in the same way in which they are formed in the camera or telescope), but that the microscopical image is very largely affected by the peculiar manner in which the *minute* constitution of the object gives rise to the phenomena of diffraction.

It is hardly necessary to say that Professor Abbe's discovery constituted a most important innovation upon the views formerly current (as much so as the spectroscope and the telephone in chemistry and physics). The honour of the discovery belongs to him alone, no hint of it having been previously given, and no one having even seen what every one can now easily see, a "diffraction spectrum" in the Microscope.

(a) *Minute Objects.*

The phenomenon of diffraction in general may be observed experimentally, as is well known, by plates of glass ruled with fine lines. Fig. 91 shows the appearance presented by a single candle-flame seen through such a plate, an uncoloured image of the flame occupying the centre, flanked on either side by a row of coloured spectra of the flame, which grow dimmer as they recede from the centre. A similar phenomenon may also be produced by dust scattered over a glass plate, and by other objects whose structure contains very minute particles, the light suffering a characteristic change in passing through such objects, that change consisting in the breaking up of a parallel beam of light into a group of rays, diverging with wide angle, and forming a regular series of maxima and minima of intensity of light, due to difference of phase of vibration. The formula in which these phenomena are expressed is that known as Fraunhofer's formula, which was first published in 1821.[*]

FIG. 91.

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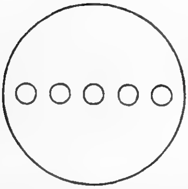
[*] Denkschr. k. Bayer. Akad., viii.

Dealing now with the phenomena of diffraction as more immediately connected with microscopical vision, the existence and influence of the diffraction spectra in the Microscope may be demonstrated theoretically and experimentally. The theoretical demonstration has been given by Professor Abbe in his original paper,* and a simple and intelligible exposition will also be found in Naegeli and Schwendener's 'Das Mikroskop.' †

The point which is of importance for our present purpose in Abbe's researches is that Fraunhofer's formula was for the first time applied to microscopical vision, and the influence of the diffracted light on the image investigated.

If a diaphragm-opening be interposed between the mirror and a plate of ruled lines placed upon the stage, the appearance shown in Fig. 92 will be observed at the back of the objective on removing the eye-piece and looking down the tube of the Microscope. The central circle is an image of the diaphragm-opening produced by the direct, so-called non-diffracted, rays, while those on either side are the diffraction images produced by the rays which are bent off from the incident pencil. In homogeneous light the central and lateral images agree in size and form, but in white light, as might have been expected, the diffracted images are radially drawn out, with the outer edges red and the inner blue (the reverse of the ordinary spectrum), forming, in fact, regular spectra, the distance separating each of which varies inversely as the closeness of the lines, being, for instance, with the same objective twice as far apart when the lines are twice as close.

FIG. 92.



The formation of the microscopical image is explained by the fact that the rays collected at the back of the objective, depicting there the direct and spectral images of the source of light, reach in their further course the plane which is conjugate to the object and give rise there to an interference phenomenon (owing to the connections of the undulations), this interference effect giving the ultimate image which is observed by the eye-piece, and which therefore depends essentially on the number and distribution of the diffracted beams which enter the objective.

That the diffraction spectra are not mere superfluous and accidental phenomena but are in fact directly connected with the image seen by the eye, has been very fully demonstrated by Professor Abbe at a special meeting held for the purpose, and recorded in our Proceedings in the Journal, as well as in papers by Mr. Stephenson before this Society, by Dr. Fripp before the Bristol Naturalists' Society, and by ourselves before the Quekett Microscopical Club. These papers are printed at full length in the Proceedings of the respective Societies, with the illustrations used, so that we may

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* See references collected in this Journal, ii. (1879) p. 651.

† 2nd ed. (1877), English Translation (1881), p. 233.

confine ourselves here to a few only out of the numerous cases in which the special influence of the diffraction spectra may be demonstrated.

The first experiment shows that with, for instance, the central beam, or any one of the spectral beams alone, only the contour of the object is seen, the addition of at least one diffraction spectrum being essential to the visibility of the structure.

Fig. 93 shows the appearance presented by an object composed of wide and narrow lines ruled on glass, when viewed in the ordinary way with the eye-piece in place, and Fig. 94 the appearance presented at the back of the objective, when the eye-piece is removed, the spectra being ranged on either side of the central (white) image, and at right angles to the direction of the lines; in accordance with theory, they are farther apart for the fine lines than for the wide ones.

Fig. 93.

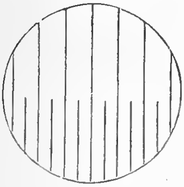
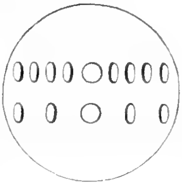


Fig. 94.



If now, by a diaphragm at the back of the objective, like Fig. 95, we cover up all the diffraction spectra, allowing only the direct rays to reach the image, the object will appear to be wholly deprived of fine details, only the outline remaining and every delineation of minute structure disappearing just as if the Microscope had suddenly lost its optical power, see Fig. 96.

Fig. 95.

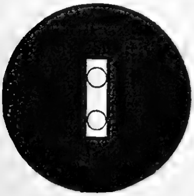
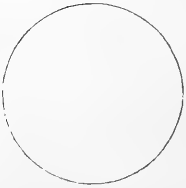


Fig. 96.



This illustrates a case of the *obliteration* of structure by obstructing the passage of the diffraction spectra to the eye-piece.

The second experiment shows how the appearance of fine structure may be *created* by manipulating the spectra.

If a diaphragm such as that shown in Fig. 97 is placed at the back of the objective, so as to cut off each alternate one of the upper row of spectra in Fig. 93, that row will obviously become identical with the lower one, and if the theory holds good, we should find the image of the upper lines identical with that of the lower. On replacing the eye-piece we see that it is so, the upper set of lines are doubled in number, a new line appearing in the centre of the space between each of the old (upper) ones, and upper and lower set having become to all appearance identical (Fig. 98).

Fig. 97.

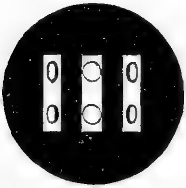


Fig. 98.

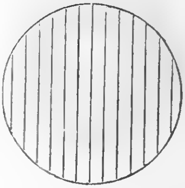


Fig. 99.

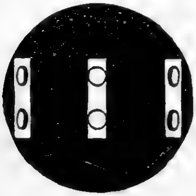
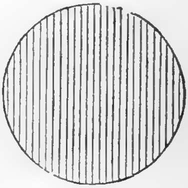


Fig. 100.



In the same way, if we stop off all but the outer spectra as in Fig. 99, the lines are apparently again doubled, and are seen as in Fig. 100.

Fig. 101.

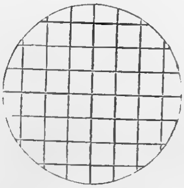
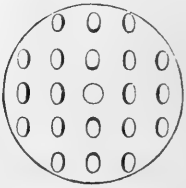


Fig. 102.



A case of apparent creation of structure similar in principle to the foregoing, though more striking, is afforded by a network of squares such as Fig. 101, having sides *parallel* to this page, which gives the spectra shown in Fig. 102, consisting of vertical rows for the horizontal lines and horizontal rows for the vertical ones. But it is readily seen that two diagonal rows of spectra exist at right angles to the two diagonals of the squares, just as would arise from sets of lines in the direction of the diagonals, so that if the theory holds good we ought to find, on obstructing all the other spectra and allowing

FIG. 103.

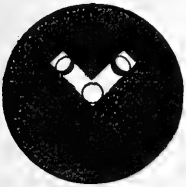
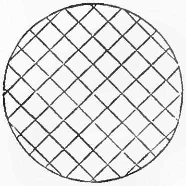


FIG. 104.



only the diagonal ones to pass to the eye-piece, that the vertical and horizontal lines have disappeared, and two new sets of lines at *right angles to the diagonals* in their place.

On inserting the diaphragm, Fig. 103, and replacing the eye-piece, we find, in the place of the old network, the one shown in Fig. 104, the squares being, however, smaller in the proportion of $1 : \sqrt{2}$, as they should be in exact accordance with theory.

An object such as *Pleurosigma angulatum*, which gives six diffraction spectra arranged as in Fig. 105, should according to theory show markings in a hexagonal arrangement. For there will be one set of lines at right angles to *b a e*, another set at right angles to *c a f*, and a third at right angles to *g a d*. These three sets of lines will obviously produce the appearance of fields arranged as shown in Fig. 106. The exact shape of the bright spot of every field is shown by theory to be *circular*, which is readily verified by observation.

FIG. 105.

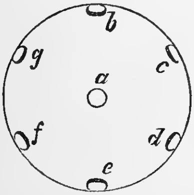
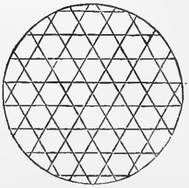


FIG. 106.



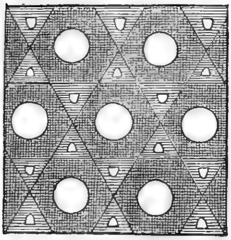
A great variety of other appearances may be produced with this same arrangement of spectra. Any two adjacent spectra with the central beam (as *b c a*), will form equilateral triangles, and give hexagonal markings. Or by stopping off all but *g c e* (or *b d f*) we again have the spectra in the form of equilateral triangles; but as they are now further apart, the sides of the triangles in the two cases being as $\sqrt{3} : 1$, the hexagons will be smaller and three times as numerous. Their sides will also be arranged at a different angle to those of the first set. The hexagons may also be entirely obliterated by admitting only the spectra *g c* or *g f* or *b f*, &c., when new lines will appear parallel, at right angles, or obliquely inclined to the median line.

By varying the combinations of the spectra, therefore, different figures of varying size and positions are produced, all of which cannot of course represent the true structure.

Not only, however, may the appearance of particular structure be obliterated or created, but it may even be *predicted* before it has been actually seen under the Microscope. If the position and relative intensity of the spectra in any particular case is given, the character of the resultant image can be worked out by mathematical calculations solely.

A remarkable instance of such a "prediction" (as we may call it), is to be found in the case recorded by Mr. Stephenson,* where a mathematical student, who had never seen a diatom, worked out the purely mathematical result of the interference of the six spectra b–g of Fig. 105 (identical with *angulatum*) giving the drawing copied in Fig. 107. The special feature was the *small* markings between the hexagons, which had never been seen on *angulatum*.

FIG. 107.



On Mr. Stephenson, however, re-examining a valve—stopping out the central beam, and allowing the six spectra only to pass—the small markings were found actually to exist, though they were so faint that they had escaped observation until the result of the mathematical deduction had shown that they *ought* to be seen.*

It is therefore shown that dissimilar structures give identical microscopical images when the difference of their diffractive effect is removed, and conversely similar structures may give dissimilar images when their diffractive images are made dissimilar. A purely dioptric image produced by homofocal rays answers point for point to the object on the stage, and therefore would enable a safe inference to be drawn as to the actual nature of that object: the interference images of minute structure, however, stand in no direct relation to the nature of the object, so that the visible indications of structure in a microscopical image are not always or necessarily conformable to the actual nature of the object examined.

Or as Professor Abbe puts it, minute structural details are not as a rule imaged by the Microscope geometrically or dioptrically, in accordance with the real nature of the object, and cannot be interpreted as morphological but only as physical characters, not as *images* of material forms, but as *signs* of material differences of composition of the particles composing the object, so that nothing more can safely be inferred from the image as presented to the eye than the presence in the object of such structural peculiarities as will produce the particular diffraction phenomena on which the images depend.

The larger the number of diffracted rays admitted, the greater the similarity between the image and the object, a true image of the real structure being produced only when all the diffracted rays from

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* See this Journal, i. (1878), p. 186.

the object are admitted. The consideration of the diffraction pencils, their admission or non-admission into the field, bears therefore, not merely on the resolving power but on the *delineating power* of the Microscope, i. e. on the fundamental aim of microscopical observation *to see things as they are.*

Those who have recognized these facts of microscopical vision, know how difficult it has been to induce those who have always looked upon the Microscope as essentially belonging to geometrical optics not merely to recognize that it has largely passed into the domain of physical optics, but even to listen to the suggestion. The difficulty is not in their grasping the fact when it is once explained to them, as the experiments which illustrate it are very simple; but is of the same kind as that which prevented our forefathers even investigating the (to them) absurd allegation that the earth revolved on its axis.*

(b) *Coarser Objects.*

It will be useful to note for those who have not had the opportunity of following the continuation of the researches of Professor Abbe, that they have enabled him to complete the diffraction theory.

In his original paper Professor Abbe established, as we have shown above, the application of the theory to the delineation of minute structures which by their diffractive effect produce a perceptible breaking up of the incident (transmitted or reflected) rays, the images of the coarse parts of microscopical objects (measured by considerable multiples of the wave-length) being treated as depicted on the ordinary dioptric method, giving what was called the "dioptric image," the minute structural parts giving the "interference image."

The further researches showed that strict dioptrical delineation, by simple collection of the emitted rays to a conjugate focus, is confined to the delineation of self-luminous objects, those which radiate by transmitted or reflected light being depicted on the interference principle.

The explanation of the mode of delineation of coarse structures would then stand thus:—The image of any given structure becomes, as we have seen, more and more similar to the true composition of the object, when a greater and greater portion of the whole diffraction group is admitted to the objective, or the lost portion is reduced more and more. The dissimilarity of the microscopical image in relation to the object depends only on the *loss of diffracted rays*, and is therefore in general increased when the objective's aperture excludes more and more of the bent-off beams. The image of a structure which is

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* A striking instance of this difficulty will be found in the statement which recently appeared in print that "these mysterious spectra are simply visionary" (Eng. Mech., xxxii. 1880, p. 300), a statement which was made with so much genuine conviction that it *must* be true that it was not thought necessary to check the assertion by an experiment which it would not have taken five minutes to make! And this in an age which has seen sound conveyed to a distance by a beam of light (or heat), and in which no one any longer ventures to discredit in advance a reported new discovery merely by the suggestion that it outrages the notions that we were taught in early life, and which we had got to believe were so simple and fundamental that it was impossible they could be either erroneous or capable of qualification.

delineated by means of one or a few diffraction beams, is in general a more imperfect and incomplete image than another which is depicted by means of a greater part of the total diffraction group. The images of coarse objects are perfectly similar to the objects, because even small apertures are capable of admitting the *whole group* up to the limit of vanishing intensity of the deflected rays.

To put it in another way. The interference image of any object must become more and more similar to a simple dioptric image when the elements become coarser and coarser, and the breaking up of the rays by diffraction is confined to smaller and smaller angles. Whenever these angles of the diffraction groups are very small compared to the aperture angle of the objective, the result of the interference effect is the same as if there were *no* diffraction at all, and the object were depicted as if self-luminous.

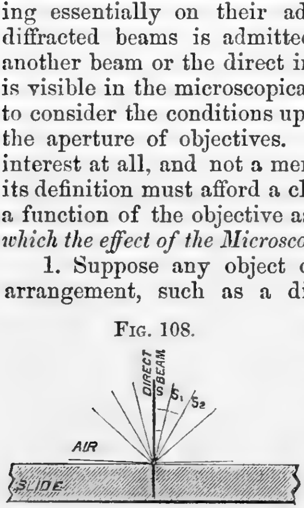
(2) The Delineating Power of Objectives and Aperture.—So far we have not supposed the existence of immersion objectives or of apertures exceeding the equivalent of 180° angular in air, indeed Prof. Abbe's views were developed at a period when opticians had not recognized the possibility of constructing objectives with so large apertures.

The two considerations with which we have however dealt—the existence of apertures in excess of 180° in air, and the function of increased aperture—may now be combined.

The beams of diffracted light which emanate from any structure are, as we have seen, by no means indifferent and accidental things in the action of the Microscope, the efficiency of the instrument depending essentially on their admission. Unless at least one of these diffracted beams is admitted by the objective, together with either another beam or the direct incident pencil, no indication of structure is visible in the microscopical image. It will be important therefore to consider the conditions upon which this admission depends, that is, the aperture of objectives. If aperture is of any general scientific interest at all, and not a mere matter of abstract dioptrical doctrine, its definition must afford a clear and correct indication of so important a function of the objective as *the admission or non-admission of rays on which the effect of the Microscope is based*, that is, of its *delineating power*.

1. Suppose any object composed of minute elements in regular arrangement, such as a diatom valve; and to confine the consideration to the most simple case, suppose it illuminated by a *narrow axial* pencil of incident rays. If this object is observed successively in air and balsam, or any other dense medium of refractive index n, the radiation from every point of the object is, in consequence of the diffraction effect, composed of an axial pencil S, Fig. 108 (the direct continuation of the incident rays), and a number of bent-off pencils S_1, S_2 . . . inclined at the angles w_1, w_2 the first, second . . . deflected beams on all sides. Denoting by λ the wave-

FIG. 108.



length of the light (of any definite colour) in air, and by δ the distance of consecutive elements of the structure, then the wave-length of the same rays within a medium of the refractive index n will always be $\frac{\lambda}{n}$. By the Fraunhofer formula the angles w_1, w_2 . . . of the first, second . . . deflected beam within the medium are defined by the equations

$$\text{Sin } w_1 = \frac{\frac{\lambda}{n}}{\delta}; \quad \sin w_2 = 2\,\frac{\frac{\lambda}{n}}{\delta},$$

or

$$\text{Sin } w_1 = \frac{\lambda}{n\,\delta}; \quad \sin w_2 = 2\,\frac{\lambda}{n\,\delta}$$

(n is of course $= 1$ for air).

In passing from air to the medium n the *sine* of the deflection angle of the first, second . . . bent-off beam is *reduced*, therefore, in the exact proportion of n, and the angle itself is reduced also—that is, the whole fan of the diffracted rays is *contracted* in comparison with its extension in air.

If now any dry objective (with a given angular semi-aperture u) is capable of gathering-in from air the first, or the first and second diffraction beams on every side of the axial pencil, another objective with a more dense front medium of the refractive index n, will be capable of admitting, from within the dense medium, exactly the *same* beams (no more and no less), if its angular semi-aperture v is *less than* u in the proportion—

$$\sin v : \sin u = 1 : n,$$

or if

$$n \sin v = \sin u,$$

all other circumstances—object and illumination—remaining the same.

For example, a diatom for which the distance of the striæ is $0 \cdot 6\ \mu$, will give the *first* bent-off beam of green light ($\lambda = 0 \cdot 55\ \mu$), in *air* under an angle of $66 \cdot 5°$. This will be just admitted by a dry objective of 133° angular aperture. In *balsam* ($n = 1 \cdot 5$), the same pencil will be deflected by $37 \cdot 5°$ only, and would be admitted therefore by an objective of not more than 75° balsam-angle. Again, if the distance of the lines should be greater, as $1 \cdot 2\ \mu$, the *second* deflected beam would be emitted in *air* under an angle of $66 \cdot 5°$, but in *balsam* the *third* would attain the same obliquity. Whilst now the dry objective of 133° air-angle cannot admit more than the two first diffraction beams on each side of the axis, the immersion of 133° balsam-angle is capable of admitting from balsam three on each side under exactly the same illumination.

It follows, therefore, that a balsam-angle of 75° denotes the same aperture as an air-angle of 133°, and a balsam-angle of 133° a much greater aperture than an air-angle of the same number of degrees, and in general two apertures of different objectives must be equal if the sines of the semi-angles are in the inverse ratio of the refractive index of the medium to which they relate, or, which is the same thing, if the product ref. ind. × sine of the angular semi-aperture ($n \sin u$) yields the same value for both.

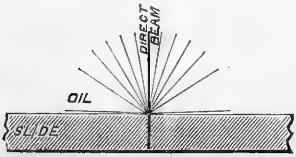
Thus the *unequal equivalent* of equal angles is shown in this way also, as well as by the purely dioptrical method, and numerical aperture ($n \sin u$) is seen to be the true measure of the greater or smaller capacity of an objective for collecting light—i. e. the true image-forming light—from the object.

2. Suppose one and the same (structured) object to be observed by a dry objective of a given air-angle, at first in air uncovered, and then in balsam protected by a cover-glass. According to Fraunhofer's law, the group of diffracted beams emitted from this object *in balsam* is *contracted* in comparison to the group in air in the ratio of the refractive index. But according to the law of refraction, this group, on passing to *air* by the plane surface of the covering-glass, is *spread out*—the sines of the angles being compared—in the ratio of the same refractive index. Consequently the various diffraction pencils, the first, second . . . on every side, after their *transmission into air*, have exactly the same obliquity which they have in the case of direct *emission in air* from an uncovered object.

If, now, any dry objective of, say, 133° air-angle is capable of admitting a certain number of these pencils from the uncovered object, it will admit exactly the *same* pencils from the balsam-mounted object. The contracted cone in balsam of 75° angular aperture embraces all rays which are emitted in air within a cone of 133°.

It is, therefore, shown in this mode also, as it was before dioptrically, that there is no loss of aperture by mounting the objects in balsam or other dense medium; the aperture of an objective, whether great or small, is *never* cut down thereby. No ray which could be taken in from the uncovered object is lost by the balsam mounting. The full and undiminished aperture of a dry objective always bears upon the object with every method of mounting, provided there is a plane surface of emergence.

FIG. 109.



3. A comparison of Figs. 108 and 109 will show that a cone of 82° within the balsam medium embraces *all* the diffracted rays which are emitted from the object in air or transmitted from balsam to air. This, however, is not the totality of rays which are emitted in the balsam. The formula of Fraunhofer accounts for as many (k) diffraction beams on each side of the direct beam as are reconcilable with the condition $k \frac{\lambda}{n \delta} < 1$, because the expression gives the *sine* of the angle of deflection.

The number of the emitted beams is therefore *greater* in balsam than in air in the same ratio as the refractive index.

A structure of δ (distance of the elements) $= 4 \times 0{\cdot}55\,\mu = 2{\cdot}2\,\mu$

emits in balsam *six* distinct beams on each side of the direct beam, but in air only *four* (see Figs. 108 and 109); the fifth and sixth are completely lost in air, as there is no angle of obliquity whose sine is >1. A dry objective of an angular aperture closely approaching 180° will not even take in the fourth deflected beam, as this is deflected at an angle of 90°. But any immersion glass of a balsam-angle slightly exceeding 82° will take in the fourth, and if the balsam-angle should exceed 112° it will take in the fifth beam also, provided the object is in balsam and in optical continuity with the front of the lens.

Thus again it is shown, in agreement with the dioptrical method, that an immersion objective of balsam-angle exceeding 82° has a wider aperture than any dry objective of maximum angle can have, for it is capable of gathering in from objects in a dense medium rays which are not accessible to an air-angle of 180°.

Recalling what was before explained as to the progressive enlargement that takes place in the diameters of the emergent beams of dry, water-immersion, and oil-immersion objectives of maximum aperture (see Fig. 54), it will be readily seen how the enlarged diameters will allow of the admission of additional diffracted beams.

The action of the obliquity of the incident light may also be seen by comparing Fig. 108 with Fig. 57. In the latter case the direct beam is no longer vertical but horizontal, so that new spectra can now enter the field, and particular structure before invisible comes into view.

These conclusions are simply inferences from two well-established optical laws—that of Fraunhofer, and the law of refraction. They are supported to the full extent by observation under the Microscope. Though we cannot see the contraction of the diffraction group in the denser medium, and its subsequent extension by the transmission into air, we can directly observe the various beams at their entrance into the objective by observing the spectra in the clear opening of the system. In this way it is shown—

1. If any structure is observed successively by a dry objective of *large* air-angle, and by an immersion objective of *moderate* balsam-angle (much less than the air-angle of the former), we never lose any spectral beam which is visible with the dry objective.

2. If we examine the same object with the same dry objective at first in air, and afterwards in balsam, we always see the same spectra.

3. Observing a balsam-mounted object with a wide-angled immersion glass (balsam-angle $>$ 82°) we see *new* spectra which, under the same illumination, are never taken up by any dry objective nor by the immersion objective when the object is in air.

V. The Value of Wide-angled Immersion Objectives.

What is the result of the preceding demonstrations?

First. It is shown that, contrary to the "angular" theory, a wide-angled immersion objective *has* an aperture (in the true and legitimate sense of the term as meaning "opening") exceeding that of 180° angular in air, that is in excess of the maximum to which a dry objective can attain, so that the contrary view must now be ranked with the belief in the flatness of the earth which still lingers in places.

Second. Whilst it is conceded by all parties that increase in aperture is accompanied by an increased effect in microscopical vision, the reason cannot be explained on the "angular" view. When it is seen, however, that microscopical vision is not, as erroneously supposed, subject only to the same conditions as ordinary vision, the explanation of its true character is shown to lead to the establishment of the *diffraction*, in lieu of the *dioptrical*, theory.

Thirdly. Dry objectives must be considered to represent an imperfect phase of construction *so far as regards the delineation* (not "resolution" merely) *of very minute objects.* Dry objectives are and will always be of the highest practical value in those lines of research in which low and moderate apertures are sufficient for the perfect delineation of the objects under investigation. As soon, however, as minute objects are observed which require *high amplifications* in order to be *seen*, dry objectives cannot compete with immersion inasmuch *as high apertures are necessary in order to obtain perfect delineation.* No improvements in construction, therefore, can render a dry objective, whose aperture is limited to 1·0, equal for the delineation of minute objects to a wide-angled immersion objective whose aperture is limited only by the higher figure which represents the refractive index of the denser immersion medium.

For any of the purposes, therefore, for which the delineation of very minute objects is required in the Microscope—and it need hardly be said that this is by no means *all* purposes—a perfectly constructed wide-angled homogeneous-immersion objective is necessarily to be preferred to all others, for the simple reason that it enables us to see more, and more perfectly.

It will be recognized that this is not a merely abstract result, of interest to no one but the optical mathematician, but that it is a *practical* result in the fullest sense of that term.

β. Collecting, Mounting, and Examining Objects, &c.

Aeroscopes.—Dr. R. L. Maddox comments upon the remarks of M. Miquel on this subject,* particularly in reference to his statement that his aeroscope à girouette gathers 100 times more germs than the aeroconiscope Dr. Maddox used in 1870.

The aeroconiscope was not exposed, as supposed by M. Miquel, for the entire twenty-four hours, except in one case, but was removed during rain and at night, except on one other occasion when it was left exposed for eighteen hours. Tabulating the total number of hours for the several daily exposures in the different months, the result is as follows:—

April 19	—Exposures	157	hours,	against	total time,	456	hours.
May 24	"	213½	"	"	"	556	"
June 23	"	235	"	"	"	652	"
July 19	"	225	"	"	"	456	"
Aug. 10	"	116	"	"	"	240	"
Sept. 22	"	203	"	"	"	528	"
Oct. 26	"	175	"	"	"	624	"
Nov. 12	"	90	"	"	"	165	"

The position of the apparatus was much sheltered, especially by the houses, from the more prevalent winds, S.S.W. and W. The garden was surrounded by a wall and contained many trees. The small village lay chiefly at the back of the house, north and east, a brewery being at a considerable distance away. The house faced a large open field, with the Solent beyond, the town of Southampton being at some distance on the north and north-west. The instrument was also coarsely made, the funnels being of tin, so doubtless many particles were arrested on their path to the thin cover-glass.

The enumeration was real, and made immediately upon the thin cover being removed, and not by comparison of the relations between the surface of the exposed gathering-glass and the field of the Microscope. Moreover, neither pollen nor starch grains were counted, which enter into M. Miquel's category, to be allowed for by a percentage which, to be correct, should vary according to the season; for in summer we may expect more pollen, and in the chief brewing months more cells of yeast and starch from the breweries of a large city. May there not also be some doubt, Dr. Maddox asks, of the correctness of M. Miquel's method of calculating the results of the exposures of *forty-eight hours*, for is it not possible that many yeast-cells and small torulæ may within that period, on warm moist days especially, develope, and the attempt to distribute the dust equally throughout the sticky material used, by means of a needle-point, be liable to detach or disjoint the newly formed or secondary cells, and thus add directly to the original number for calculation?

No doubt in strong winds many of the lighter particles are carried much higher than the level of the instrument; nor is there any possibility of obtaining exactness unless by using an aspirator that could draw through the instrument a column of air of a given height, always turned to face the wind; for if the velocity of the latter exceed the

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* See this Journal, iii. (1880) p. 1032.

draught of the aspirator, a large number of particles must be carried past without entering the aeroscope; and if the power of the aspirator exceed the force of the wind, it would tend to lift the light but quiescent particles in the immediate proximity.

The object which engaged Dr. Maddox's attention at the time was to ascertain by cultivation whether the collected germs were capable of germinating under the measures used,—in fact, whether they were living or dead; hence glycerine was discarded. It is gratifying to see that M. Miquel intends to continue bringing his great patience and ingenuity to the experimental examination by cultivation, in flasks, of the "Schizophytes de l'atmosphère," the more important part of the inquiry. The advantages he enjoys at the Park of Montsouris have already yielded most interesting results. Although it is not likely that we shall ever be able to exactly imitate the processes at work, as temperature, moisture, pabulum, &c., which lead to rapid development of septic elements within a highly organized living being; yet the recognition of trustworthy cultivations out of the body is amongst the first conditions for understanding the agency, whether hurtful or otherwise, of the minute organisms which so largely surround us, enabling us to test their properties by inoculations on the lower animals at any stage of their cultivation. Still such studies will require to be extended over a large area in different countries before we shall be able to arrive at their real estimate in reference to disease, whether of man or animals.

Slip-cleaning Instrument.*—Mr. Searle brought this instrument before the members of the Postal Microscopical Society at their last meeting. It consists of a flat piece of wood 15 × 4 × $\frac{1}{2}$ inch. Along each side of this and close to the edge is fastened a slip of wood 12 × $\frac{1}{2}$ × $\frac{1}{4}$ inch, thus leaving a clear space of 3 inches between them, and in which the slips are arranged for cleaning. Two other loose strips 14 × $\frac{1}{2}$ × $\frac{1}{4}$ inch are now placed upon the ends of the glass, and are each secured at one end by being slipped into a staple. That portion of the wood on which the slip rests is padded with cloth. The rubber for polishing the centre of the slips is made by glueing two thicknesses of cloth on the end of a large cotton reel; a piece of washleather is stretched over the cloth and secured by being tied to the middle of the reel. It is desirable to have two of these padded reels, one to use with putty powder, the other to give the final polish.

"Opaque" Illumination by the Vertical Illuminator.—On this subject Professor J. E. Smith remarks † that definition of surface (as distinguished from "penetration") is *par excellence* the legitimate as well as the safest field for microscopical investigations of an advanced nature over objects more or less opaque.

"All attempts to illuminate objects by reflected light under high amplifications had signally failed, until about five years ago, when Mr. Geo. W. Morehouse, of Wayland, N.Y., made the important dis-

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* 'Northern Microscopist,' i. (1881) p. 68.

† Amer. Journ. Micr., v. (1880) pp. 204–6.

covery of the conjoint use of the vertical illuminator with American *immersion* objectives of wide balsam apertures.* By way of demonstration, Mr. Morehouse exhibited the *Podura* scale under amplifications of 4000 diameters, as well as other objects.

"Thus it appears that until five years ago there was no known means of working high powers with reflected light, and when we remember that the vertical illuminator proved to be a difficult instrument in the hands of one not expert either in its use or that of the wide-apertured objectives—that probably 50 per cent. of those who have made the attempt have failed to use it successfully—the reasons become apparent *why* so little has been accomplished in this direction.

"This is a *natural* field of Microscope investigation; we thus see things through the Microscope as we see them day after day with the naked eye, namely, by light reflected from the surface. It often thus occurs that such eye examinations of the surface suggest the propriety of dissecting the object into smaller and smaller parts, so that the object may be further inspected in detail. The same holds good when it is under the objective and vertically illuminated.

"The wider the balsam aperture of the immersion objective the better its conjoint work with the vertical illuminator. Here we have additional evidence of the value of wide apertures.

"Under the vertical illuminator the dry valves of *S. gemma* surrender their true structure. It will be seen that these shells are enveloped in an *exceedingly* thin membrane, which, in most cases, is ruptured, or torn from certain portions of the shell, and that it is only through the opening thus formed that the underlying 'markings' are truly seen. If the same valve be viewed by transmitted light the image will be shown falsely owing to the illumination."

[See the next note as to this *not* being "*opaque*" illumination.]

Amphipleura pellucida by Reflected and Transmitted Light.—At the ordinary meeting of the Society on 10th November, 1880, Mr. T. Powell, jun., exhibited *A. pellucida* (dry on cover-glass) in a somewhat novel manner—illuminated from above and below at the same time.

With one lamp placed at the side, the light was reflected by the vertical illuminator upon the posterior surface of the objective, and thence condensed upon the object, the lens acting as the condenser for the illumination and as object-glass at the same time. By the adjustment of a side diaphragm applied to the vertical illuminator, and by rotating the object into the required position, this illumination developed an appearance of "dotted" superficial structure. Another lamp was used to direct a pencil through the ordinary achromatic condenser of Powell and Lealand. By the slot diaphragm transmitting a small pencil refracted very obliquely through the margin of the condenser, this illumination exhibited the usual transverse striæ. A screen was arranged to cut off the illumination from either lamp, so that the object could be seen by either illumination successively.

The object was viewed by the new $\frac{1}{12}$ oil-immersion (with cor-

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* See this Journal, ii. (1879) p. 194.

rection-adjustment) of Mr. T. Powell, jun. The illumination by the vertical illuminator is well known to be one of the severest tests for the corrections of an objective; and the lens, it may be said, bore the test excellently. Its large aperture provided abundance of light, so that the fourth or fifth eye-piece could be used with either kind of illumination.

It was pointed out by Mr. Stephenson at the meeting in March that the illumination by the Vertical Illuminator had been erroneously supposed to be in this case "opaque"; whereas, in fact, the light is *totally reflected* from the internal surface of the base of the object. The proof of this is that no objective whose limit of aperture does not (approximately) exceed twice the critical angle from glass to air (82°) will illuminate the object; the whole (or very nearly so) of the light is transmitted through the object as it is not *opaque* enough to reflect back by ordinary reflection sufficient light to produce an image of its surface. But objectives of greater aperture provide an outer zone of rays beyond the critical angle; these rays cannot emerge at the base of the cover-glass of a dry mount adherent thereto *except* where the object adheres; the rays then pass into the object and suffer total reflection (to a great extent) at *its* base, and thus provide extremely oblique reflected light, which is transmitted upwards through the body of the object, and renders the surface structure visible.*

The late F. A. Nobert.—At the March meeting of the Society the announcement was made of the death of Mr. F. A. Nobert, of Barth, Pomerania, whose rulings of fine lines on glass have for many years past been regarded as marvels of dexterity by the scientific world. Mr. Nobert's fame is especially connected with the production of test-plates for the Microscope, particularly the plate known as the 19-band plate, on which successive bands of lines are ruled of increasing fineness of division, from the rate of 1000 to the Paris line to 10,000 (equal approximately to 112,000 to the English inch). It was formerly Mr. Nobert's opinion that the last four bands of his 19-band plate would never be seen resolved in the Microscope. This opinion he was constrained to withdraw after careful inspection of photographs of the whole series of bands by Dr. J. J. Woodward, of the Army Medical Museum, Washington, U.S.A., from which an accurate count of the lines actually ruled was made by Dr. Woodward, and admitted by Mr. Nobert. Mr. Nobert then proceeded to make a new plate of 20 bands of lines varying from 1000 to 20,000 to the Paris line. The lines on the tenth band in this latter plate corresponded in fineness of division to the 19th band of the former plate. The microscopists of the future have therefore Nobert's legacy before them to resolve the lines on the later test-plate. Mr. Nobert was extremely reticent as to the method of producing his fine rulings, and it is doubtful if he has communicated to any one the secret of his process of making and adjusting the ruling points.

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* See the discussion at the March meeting, *infra*, p. 373.

PROCEEDINGS OF THE SOCIETY.

ANNUAL MEETING OF 9TH FEBRUARY, 1881, AT KING'S COLLEGE, STRAND, W.C., THE PRESIDENT (DR. BEALE, F.R.S.) IN THE CHAIR.

The Minutes of the meeting of 12th January last were read and confirmed, and were signed by the Chairman.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society given to the donors.

	From
Frey, H.—Das Mikroskop und die Mikroskopische Technik. 458 pp. and 403 figs. 7th ed. (8vo. Leipzig, 1881) ..	*The Author.*
Diagram illustrating the Demonstration as to the Apertures of Dry and Immersion Objectives	*Mr. Crisp and Mr. Stewart.*
Models illustrating the "Hemisphere Puzzle" in 2 forms ..	*Mr. Crisp.*

Mr. Crisp said that in the discussion on aperture, at the last meeting, he had confined himself to pointing out that the photometrical test on which the aperture question had then been rested was founded on an entire mistake, for even assuming for the sake of argument that such a test could properly be applied in the way and to the extent propounded, the conclusion drawn was vitiated by the fact that the radiation of light in air, water, and oil, was not identical, as supposed, but varied as the squares of the refractive indices.

It would, however, he thought, be advisable (having regard to the reappearance at that meeting of some of the old fallacies which it was supposed had died out) to have in the Journal a statement of the leading points of the aperture question, not restricted to one aspect only, but dealing with it in *all* its aspects.

With this view he had prepared some notes, which would appear in the next Journal (see p. 303), and he now laid before the Society an enlarged copy of the diagram which accompanied the demonstration that no dry objective *could* have so large an aperture as an immersion objective of balsam-angle exceeding 82°. In the face of this demonstration it was impossible to accept the invitations that were at times made to see the apertures of objectives measured. As well might they assist at a measurement of the three squares on the sides of a right-angled triangle in support of the view that the large square was *not* equal to the two smaller ones, in lieu of referring the demonstrator to the 47th Prop. of the 1st Book of Euclid.

With the diagram he also presented two glass "models" illustrating the "hemisphere puzzle," in remembrance of the most curious error that had ever puzzled theoretical or practical microscopists. It would be plainly seen that the hemispheres *did* magnify exactly $\frac{3}{2}$ times, and that the smaller one converted an inch objective into a $\frac{2}{3}$ inch, the latter utilizing, however, the same large diameter of the back lens as the lower-power 1 inch.

Professor Abbe's Note on a fluid for homogeneous immersion was read by Mr. Stephenson, who said he had just received a letter from Professor Abbe, informing him that his assistant, Dr. Riedel, had lately found two fluids suitable for homogeneous-immersion objectives.

(1) The first is a solution of gum *dammar*, dissolved in hot oil of cedar-wood. The oil which is obtainable in Germany has a refractive index of 1·51 *only*, but by the dammar this can be raised to 1·54. This solution is, however, rather highly coloured, and of course somewhat sticky. But if it is *carefully distilled*, it becomes sufficiently pale and loses its stickiness. It appears that the distillation causes a certain molecular change or *decomposition* of the resin, by which its stickiness is destroyed. By diluting the strong solution (which contains a small portion only of the resin) with pure cedar-oil, every index from 1·51 to 1·53 can readily be obtained. Professor Abbe takes 1·52 *exactly* as his standard, at a temperature of 18° Cent. It is *unchangeable*, and, like pure cedar-oil, does not act upon sealing-wax, or shellac, varnish.

A very important point, to which he (Mr. Stephenson) had previously referred in that room, is the necessity of determining the *dispersive* power of all fluids used for this purpose; and with respect to this, Professor Abbe remarks that, although other resins might be used in a similar way, all those which he has tried give *too large an increase of dispersive power*, which is not the case with *dammar*, and consequently the new fluid described by him is in every respect *very near* to fluid crown.

(2) The other medium is a solution of *iodate of zinc* in Price's ordinary glycerine ($n = 1·46$). This salt is *very* soluble in glycerine, and a refractive index of 1·56 or more can be readily obtained, and there is therefore no difficulty in making a solution of 1·52, which is the standard index at 18° Cent. Like glycerine, it is of course hygroscopic, and its use therefore requires some care; at the same time, Professor Abbe states that it is as inaggressive as the solution of sulpho-carbolate of zinc or of chlorate of cadmium, whilst it is far less sticky; provided the refractive index has really been raised to 1·52 only. Its dispersive power is slightly in excess of the solution of *dammar* in cedar-oil. (Samples of the new fluids were exhibited.)

Professor Abbe has furnished Mr. Zeiss with a new formula for homogeneous $\frac{1}{8}$ths having a numerical aperture of 1·40 and adjusted for the new fluids.

Mr. John Mayall, jun., said that at the December meeting he exhibited a stage constructed by Mr. Tolles, which he then stated to be the thinnest that had been made (see p. 115). It appeared, however, that Messrs. Watson had, quite independently of Mr. Tolles, made a stage of a similar kind, which he now exhibited. The stage was thinner than that of Mr. Tolles, so that it appeared to be really the thinnest mechanical stage yet made (see p. 300).

Mr. Crisp exhibited two Microscopes by Messrs. Swift and Son, the first being their "Challenge" model, fitted with Radial Traversing

Substage Illuminators (see vol. iii. (1880) p. 867), and with the fine adjustment by means of a differential screw at the nose-piece; the second being their modification of "Wale's Working Microscope" (*ib.* p. 1045), with improved fine adjustment (see p. 296).

The Report of the Council was read by Mr. Stewart (see p. 369).

Mr. Beck said he had much pleasure in proposing the adoption of the Report, which he felt needed no comments from him to recommend it after the hearty way in which it had been received by the Meeting. He would only add that the Society was deeply indebted to Mr. Crisp for his continued services, particularly in connection with the Journal. He moved—"That the Report now read be received and adopted."

The motion was seconded by Mr. Sigsworth, and was carried unanimously.

Dr. Matthews said he should like to make an observation as to the illustration of instruments and apparatus in the Journal; if that involved any considerable reduction in the number of plates illustrating papers in the 'Transactions,' then he thought it would be impolitic to reduce such illustrations by increasing the number of woodcuts, and rather than that should be the case he would propose that the woodcuts be confined to such as were supplied gratis.

Mr. Crisp explained that what was proposed to be done was to divide the amount available for illustrations equally between the plates and the woodcuts so as to meet as far as possible the views of both naturalists and microscopists.

Mr. Michael thought that preference should be given to illustrating original work brought before the Society for the first time.

After some further conversation Dr. Matthews moved, and Mr. Michael seconded the following resolution, which was carried *nem. diss.*

"That in future woodcuts in the Journal illustrating Microscopes and apparatus be confined to such as shall be supplied gratis, or illustrate new inventions not previously announced."

The List of gentlemen proposed as Officers and Council for the ensuing year was read by Mr. Crisp, as follows:—

President—* Prof. P. Martin Duncan, M.B., F.R.S.

Vice-Presidents—* Prof. F. M. Balfour, M.A., F.R.S.; W. B. Carpenter, Esq., C.B., M.D., LL.D., F.R.S.; * John Millar, Esq., L.R.C.P. Edin., F.L.S.; * John Ware Stephenson, Esq., F.R.A.S.

Treasurer—* Lionel S. Beale, Esq., M.B., F.R.C.P., F.R.S.

Secretaries—Charles Stewart, Esq., M.R.C.S., F.L.S.; Frank Crisp, Esq., LL.B., B.A., F.L.S.

Twelve other Members of Council—* Robert Braithwaite, Esq., M.D., M.R.C.S., F.L.S.; Charles James Fox, Esq.; * William H. Gilburt, Esq.; James Glaishier, Esq., F.R.S., F.R.A.S.; A. de Souza

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* Have not held during the preceding year the office for which they were nominated.

Guimaraens, Esq.; William J. Gray, Esq., M.D.; * John E. Ingpen, Esq.; John Matthews, Esq., M.D.; * John Mayall, Esq., jun.; Albert D. Michael, Esq., F.L.S.; Frederick H. Ward, Esq., M.R.C.S.; T. Charters White, Esq., M.R.C.S., F.L.S.

The President having appointed Mr. Suffolk and Mr. Kemp Scrutineers, the ballot was proceeded with, and upon the Scrutineers presenting their Report, he declared all the above gentlemen to be duly elected.

Mr. J. W. Stephenson, the Treasurer, then read his Annual Statement for the past year (see p. 371).

Dr. Millar moved, and Mr. Suffolk seconded, the adoption of the Report, which was carried unanimously.

Mr. Beck said he believed it had not hitherto been the practice to present anything like a balance-sheet, but he thought it would be a very desirable thing to do, so that they might periodically have some kind of statement before them as to how they stood with regard to outstanding liabilities.

Mr. Stephenson said that it had never formed any part of the business of the Treasurer to prepare a balance-sheet. His function was to take all the money which was brought to him, to give cheques in payment of such accounts as were ordered to be paid by the Council, and at the close of the year he simply rendered an account of what had passed through his hands.

The President said that their excellent Treasurer was about to retire from his office, after having performed its duties in a very able manner for a period of eight or nine years; and he was sure that the Society would not allow the subject to pass without according a very hearty vote of thanks to Mr. Stephenson for his services. They were not only indebted to him for the performance of his duties, but also for the admirable papers on optical subjects, which he had from time to time brought before their meetings. He, therefore, proposed a vote of thanks to Mr. Stephenson for his services to the Society, which was then put and carried by acclamation.

The President read his Annual Address (see p. 180).

Dr. Millar moved a vote of thanks to the President for his Address, and also that the best thanks of the Society should be given to him for the services which he had rendered to the Society during the past two years.

Dr. Braithwaite, in seconding the motion, expressed his sense of the uniform kindness and ability with which Dr. Beale had throughout discharged the duties of President.

Mr. Crisp having put the motion to the Meeting, it was carried by acclamation.

The thanks of the meeting were given to the Auditors and Scrutineers.

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* Have not held during the preceding year the office for which they were nominated.

The President said that it only now remained for him to introduce to them a President under whom the Society would, he was sure, continue to grow and flourish, and who he hoped might be able to report, at the end of his term of office, that the Fellows had continued to increase in numbers.

Professor P. Martin Duncan, F.R.S., who was very cordially received by the Meeting on taking the Chair, said that he thanked the Fellows for their kind reception, and for the honour conferred upon him. He felt the great burden that had been placed upon him in following so distinguished a President as Dr. Beale, but he assured them of his best endeavours to promote the prosperity of the Society, and to maintain that good feeling which existed amongst the Fellows. He felt that his shortcomings would be great, because he could not lay claim to any very special knowledge of one important branch of microscopical science, but he trusted that when the time came for him to give up his office, he might be able to give as good an account as his predecessor.

The following Instruments, Objects, &c., were exhibited:—

Mr. Crisp:—(1) Model of the hemisphere puzzle in two forms, one arranged on a slide for the Microscope (see p. 326). (2) Swift's "Challenge" Microscope, with radial traversing substage illuminators (see vol. iii. (1880) p. 867) and differential-screw fine-adjustment.

Mr. Dreyfus:—Two preparations by Dr. O. E. R. Zimmermann of Chemnitz, one of *Aspergillus niger*, and the other showing the aerial fruit of *Peronospora*, with the zygospores in great abundance deeper in the tissues.

Messrs. Swift and Son:—Modification of "Wale's Working Microscope," with improved fine adjustment (see p. 296).

Mr. Watson:—Thin mechanical stage (see p. 300).

New Fellows.—The following were elected *Ordinary Fellows*:—Messrs. W. Dawson, J. A. Hill, J. Hood, T. E. Jobling, C. S. Power, R.N., O. G. Pritchard, and A. H. Simpson.

REPORT OF THE COUNCIL

Presented to the Annual Meeting on 9th February, 1881.

THE Council are glad to be able to present a very satisfactory report on the position of the Society during the past year, as well financially as in respect to the accession of new Fellows, the increasing interest shown in the Meetings, and otherwise.

New Fellows.

During 1880, 47 Ordinary Fellows (including 1 restored) and 2 Ex-Officio Fellows, were elected. Fourteen Ordinary Fellows have died or resigned (1 compounder and 13 subscribers). The present list of Fellows includes, therefore, 473 Ordinary Fellows, 50 Honorary, and 88 Ex-Officio Fellows, or 611 in all.

Finances.

The net increase of revenue during the year (*exclusive* of the entrance fees of the new Fellows), has amounted to 64*l.*, and in addition the Council have been able to invest a sum of 260*l.*—an exceptionally large amount—received for Compositions, which, with 200*l.* last year, and the cash in hand, has brought the capital account to upwards of 2300*l.*

The Compositions received from existing Fellows, together with the sums received from time to time by way of donations, amount to 1935*l.*, so that the invested capital is considerably in excess of this amount,—the result of investing the whole of the Compositions without, on the other hand, releasing a proportionate sum on the death of a compounding Fellow. The Council are of opinion that, having regard to the amount of the investments, it will not be necessary any longer to adhere to this course, but that Compositions may in future be dealt with as revenue, provided the full amount due to living compounders at any time and all sums received for donations, are represented by investments, and the capital account is not reduced below its present amount.

Library, Instruments, &c.

The Donations during the past year have been acknowledged from time to time in the Proceedings of the Meetings, and include Mandl's 'Anatomie Microscopique,' 2 vols., from Dr. Carpenter, C.B.; an old model of a Microscope formerly belonging to Mr. John Quekett, from Mr. C. F. White; and, from Mr. Crisp, Smith and Sowerby's 'English Botany' (1st Ed.), 41 vols., two Microscopes, &c.

The Council have decided that some of the books should be allowed to circulate as soon as a catalogue can be prepared.

Proceedings at the Meetings.

The Council have been gratified to note the increase in the attendance at the monthly Meetings. Taking the average for the five years ending 1878 as a basis, the increase in 1879 was nearly 30 per cent., and in 1880 50 per cent.

The Council attribute this increase to the fact that the papers presented to the Meetings have for the most part been summarized and not read *in extenso*, thus leaving more time for the shorter notes, and allowing a greater variety of subjects to be dealt with, with greater interest on the part of the Fellows generally. The number of the pages of the 'Transactions' proper has been somewhat reduced; but on the balance of advantage and disadvantage, the Council understand the opinion of the Fellows to be in favour of the course which has been adopted.

Dr. J. W. STEPHENSON IN ACCOUNT WITH THE ROYAL MICROSCOPICAL SOCIETY. Cr.

1880.	£	s.	d.
To Balance brought from 31st December, 1879	116	18	6
„ One year's dividend on 789*l*. 16*s*. 8*d*. Consols	23	4	0
„ One year's interest on 1200*l*. Mortgage	59	10	0
„ Annual Subscriptions, &c.	593	9	0
„ Subscriptions commuted	262	10	0
„ Advertisements	40	14	5
„ Sale of Journals, and Reprints by the Society	23	13	2
„ Screw tool sold	0	12	6
„ Cash deposited for Medal Funds	200	0	0
	£1320	11	7

1880.	£	s.	d.
By Rent, &c., at King's College	90	18	9
„ Hall Porters	6	10	0
„ Salaries	111	0	0
„ Mr. Reeves for Collecting	21	9	0
„ Reporter	9	9	0
„ Cash paid for Journal	329	12	8
„ Books	32	2	9
„ Furniture and Alterations	10	11	4
„ Fire Insurance	1	4	0
„ Petty Cash	90	0	0
„ Printing and Stationery	47	10	9
„ Cash paid for 468*l*. 1*s*. 8*d*. Consols	462	10	0
„ Lamps	4	10	6
„ Stamped Cheque Book	0	4	2
„ Balance remaining 31st December, 1880	102	18	8
	£1320	11	7

Invested Capital, 31*st December*, 1880.

1200*l*. on Freehold Mortgage.

1257*l*. 18*s*. 4*d*. 3 per cent. Consols, including 100*l*. Quekett Memorial Fund, and 200*l*. deposited for Medal Funds.

Examined and found correct, February 7th, 1881.

W. T. SUFFOLK
THOMAS CURTIES } *Auditors.*

The Journal.

The volume of the Journal for the past year has been issued on the same basis as the previous one. The modifications proposed in the arrangement for the future have been referred to in the preface which accompanied the December number.

As a desire has been expressed that new instruments and apparatus shall, as far as possible, be illustrated as well as described, the number of woodcuts has been latterly increased, an increase which it is proposed to maintain in future, although this necessarily involves some limitation of the plates. The result, however, will be that the expenditure available for illustrating each number of the Journal will be fairly apportioned between the plates which accompany communications relating to Natural History, and the woodcuts which deal with Microscopical matters.

Whilst there appears to be no limit to the willingness of Mr. Crisp to provide material for the Journal, the Council are of opinion that it will be wise to limit the number of pages to be published annually to a maximum of 1000. The Council have come to this conclusion from the fact that at the present time the Society have the benefit of honorary editorship, but if Mr. Crisp should relinquish that position, it would in all probability be found necessary to make some provision for a paid editor.

The warmest acknowledgments of the Society are due to Mr. Crisp for the continuation of his services during the past year, as well as to the Associate Editors and the Publication Committee.

MEETING OF 9TH MARCH, 1881, AT KING'S COLLEGE, STRAND, W.C., THE PRESIDENT (PROFESSOR P. MARTIN DUNCAN, F.R.S.) IN THE CHAIR.

The Minutes of the meeting of 9th February last were read and confirmed, and were signed by the President.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society given to the donors.

	From
Hinde, G. J.—Fossil Sponge Spicules from the Upper Chalk found in the interior of a Single Flint-stone from Norfolk. 83 pp., 5 plates. (8vo. Munich, 1880.) ..	*The Author.*
Griffith Club Microscope	*Mr. E. H. Griffith.*

Mr. Crisp called special attention to the donation from Mr. Hinde, and one from Dr. N. Pringsheim, being a reprint of his paper on Chlorophyll, from the 'Jahrbuch f. Wiss. Botanik,' with coloured plates.

Also to a new portable Microscope, devised by Mr. E. H. Griffith, of New York State, and known as the "Griffith Club Microscope," which he thought reflected great credit upon the ingenuity of its designer in several respects (see p. 293).

The Death of Mr. F. A. Nobert, of Barth, in Pomerania (of "Nobert's lines" celebrity) was announced (see p. 364).

Mr. T. Powell said that he had been requested to exhibit again *Amphipleura pellucida* with the $\frac{1}{12}$-inch wide-angled immersion objective of 1·43 num. ap. (142° balsam-angle) and illuminated by the vertical illuminator (see p. 363). In place, however, of mounting the diatom on a slide, he had attached it to the under side of a cover-glass, and without any slide beneath. It appeared to raise a very interesting question, and though he could not pretend to have investigated the matter critically, he had ventured to adopt the description given to it, at the last Scientific Evening, of "opaque" illumination.

Mr. Crisp said that Mr. Powell's exhibition certainly raised a very interesting optical problem. When he first exhibited it the diatom was on a slide, and the objection to the "opaque" view had then been grounded on the supposition that the light was reflected back from the slide. Mr. Powell now showed it without a slide, so that the original objection was disposed of. In recent discussions upon the subject in America, it had been assumed that the illumination was clearly "opaque," but he thought proof was still required that it was really so, and he inclined to the view which had been suggested by Mr. Stephenson—viz. that whilst so much of the illuminating pencil (incident from above) as was within the critical angle passed through the diatom into air, that part which was beyond the critical angle could not similarly escape into air from the under surface of the valve, but was reflected upwards, and so illuminated the upper surface by *transmitted* light.

Mr. Powell said that he did not desire to be understood as by any means insisting that it was "opaque" illumination, but he might mention that he had often shown a diamond-beetle's wing illuminated as an opaque object by the "vertical illuminator."

Mr. Crisp, on removing the eye-piece of the Microscope, said that nothing could be seen at the back of the objective but portions of the bright annulus which represented the surplus aperture of the objective in excess of 180° in air.

Mr. Stephenson would like to know whether Mr. Powell had tried the experiment of reducing the aperture of the objective to the equivalent of the air-angle of 180°, by excluding the bright annulus of light. By such a proceeding, the direct light from the vertical illuminator above the objective would still fall upon the valve, and, if it were capable of reflecting light, it should of course be still visible; but he ventured to say, entirely from theoretical considerations, that beyond, perhaps, the mere outline, it would be practically invisible. Or again: if it were examined under the full aperture without any stop, but with an infinitely thin film of air between the diatom and the cover-glass, the same result would be obtained. He had no hesitation in saying that, in his opinion, it was not a case of opaque illumination, but that the diatom, adhering to the cover-glass, allowed the rays beyond the critical angle to penetrate the glass surface, and the light, passing through to the under side of the valve, was there totally reflected, and thus the valve illuminated itself. On removing the eye-piece when the object was so resolved, the diffraction spectrum and the reflected illuminating beam would be visible at the extreme edge of the back lens, on opposite sides; showing, as he had pointed out on a previous occasion, that although it was a dry object, the full aperture of the wide-angled immersion objective beyond the equivalent of 180° in air had been utilized, which could never be the case with transmitted light. In other words, the resolution in this case is exclusively effected by what have been contended to be "non-image-forming rays," or rays in excess of 180° in air. If an opaque object, such as the elytron of a beetle, were examined, it would of course reflect the light brilliantly under either of the conditions he had named; but with a transparent object, such as *A. pellucida*, this would not be so.

Mr. Powell said that the diatom was in fact invisible, as Mr. Stephenson had suggested, when the bright annulus was excluded.

Mr. T. Charters White said he had often thought that for the study of insect anatomy it would be a great advantage if they could get some kind of reagent which would render the chitinous envelope transparent; and he was at first rejoiced to hear that carbolic acid would produce this result. He was, however, disappointed to find in practice that whilst it rendered the chitinous envelope transparent, it also made the internal organs equally so. This was so serious an objection that he had resolved to try and work out the subject during the summer, with the idea of finding something else which might not be open to the same objection. He mentioned the subject now, in the hope that other Fellows would co-operate.

Dr. Matthews said he had tried carbolic acid, but the experiments which he had made were not so successful as to induce him to use it again. He produced a slide of a whole spider which had been prepared in carbolic acid. When taken out it was nearly transparent, and apparently in a very favourable condition for mounting; but it would be seen that the whole of the abdomen had collapsed, a circumstance which he could only account for by supposing that the balsam and the carbolic acid had entirely changed places. This specimen was mounted in undiluted balsam, and he had tried since to mount others in various solutions of balsam, in benzole, ether, and chloroform, and had also tried common pine resin in copaiba, but all had failed in consequence of this apparent endosmose; and he was quite at a loss what to try next. He should mention that when first mounted the spider was perfect, and all that could be wished, but the next morning it was found in its present condition.

Mr. Stewart said he was without special experience in the matter, but should like to know whether the object was made clean by the simple extraction of the watery contents, or whether there was any kind of bleaching action about it?

Dr. Matthews said he had not yet established the fact that it had a bleaching effect, but he suspected that such was the case. He regretted very much that a process which seemed to promise so well at first, should so entirely fail on account of want of balance between the fluids.

Mr. White said he could quite corroborate what Dr. Matthews had said with regard to objects mounted in the way he had described, but so far as he had been able to judge, he concluded that the action of the carbolic acid was not of a bleaching character.

Mr. Stewart mentioned that objects kept for some time in oil of cloves were exceedingly prone to bleach, and suggested that this might also be an effect of long exposure to carbolic acid.

Mr. Crisp called attention to a series of mycological preparations made by Dr. Zimmermann of Chemnitz, of which a list was laid on the table.

Mr. Swift said he should like to ask a question with regard to the gauges for the "Society" screw now supplied by the Society. He found it was taper from end to end, and should therefore be glad to know which part of it was the correct standard.

Mr. Crisp said that he was unable to answer that question at the moment, as the matter had been placed, by arrangement with the Council, in the hands of Mr. Bevington, who was not now present.

Mr. Beck considered that the only way to have a standard screw would be by turning off the thread and seeing what was the diameter of the plain cylinder. He knew from personal experience how difficult it was to work to such a pattern as that referred to by Mr. Swift.

Some discussion ensued, in which Mr. Beck, Mr. Powell, and others took part, as to the standards produced by the Assistant-Secretary, and which it was stated had been presented to the Society by the late Mr. Charles Brooke.

Mr. Curties said the question was one of so much importance to opticians that it would be desirable to have it settled, and he suggested that it should be fully discussed at the next meeting, which was arranged to be done.

Mr. Crisp explained the result of M. W. Prinz's observations on diatoms found in thin plates of "roche de Nykjöbing" (Jutland). The author had been able to obtain sections of the diatoms in a great variety of planes, and had, he considered, established that the valves of *Coscinodiscus Oculus-Iridis* and *Trinacria Regina* were traversed by small *openings*.

Mr. Stewart considered this was an additional confirmation of the view propounded by Mr. Stephenson some time ago.*

Mr. Crisp referred also to the result arrived at by Dr. Gunther's photographs.†

Mr. A. D. Michael's paper, "On a Species of Acarus, believed to be Unrecorded," was read by Mr. Stewart (see p. 212).

The President said that one found these creatures in such strange

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* See Mon. Micr. Journ., x. (1873) p. 4.

† See this Journal, iii. (1880) p. 891.

places that it was very difficult to see how they managed to exist. In looking over some fossils which had been collected during the Indian survey, and which came from a desert and had been kept dry ever since, he found a number of Acari. That they came from India with the fossils was well established, but how they obtained their nourishment was a matter of surprise.

Mr. Crisp, in reply to Dr. Edmunds, described the new $1\frac{1}{4}$-inch screw recently adopted in America for low-power objectives of wide angle, known as the "Butterfield Broad-gauge Screw" (see p. 301).

Dr. E. Cutter's paper, "On the Infusorial Catarrh of Salisbury," was read by Mr. Stewart.

Dr. Cutter confirms the view expressed by Dr. J. H. Salisbury in the 'Journal für Parasitenkunde,' that epidemic catarrh is due to the presence of infusoria,—*Asthematos ciliaris.* He maintains that they are not, as some suppose, modified ciliated epithelium, because by culture in mucus outside the body they increase in number in many ways, and they are found in morbid secretion of the conjunctiva where no ciliated epithelium exists. Moreover, those remedies only cure the disease which kill the *Asthematos.* He states that they are not, as some have insisted, the cause of hay-asthma.

The President called attention to the drawings accompanying the paper, which were of interest in connection with it.

Mr. Stewart thought it quite possible that the objects represented by the drawings might be epithelial, and yet that they might be the vehicles by which disease was propagated.

The President said they were certainly a very exceptional form of infusoria, and looked more like the ciliated cells of epithelium; still it was quite possible that there might be such forms of infusoria as these.

Mr. Crisp said that the suggestion that the radiation of light was greater in glass or oil than in air, had been supposed in some quarters to be so paradoxical and so opposed to what were regarded as the fundamental laws of optics, that he had brought for exhibition after the meeting a piece of apparatus (suggested by Professor Abbe) which would enable the fact to be appreciated without requiring an eye accustomed to photometrical estimations (see p. 343).

Mr. Shadbolt's "Further Remarks on the Apertures of Microscope Objectives" was taken as read as follows:—

"I beg to offer a few remarks upon this subject, relative to the point to which we have now advanced in the controversy.

"My last communication, together with the reply from 'the other side,' appear in the Journal for February, and certainly nothing in the latter can be found which disproves the view I have enunciated on the main point at issue, viz. whether any 'aperture' of any kind can exceed that of 180° angular in air.

"I request attention particularly to the two diagrams numbered respectively 34 and 35 on page 164 of the number of the Journal above cited.

"It is abundantly evident that a dry lens of 170° aperture (assuming such an instrument to be in existence) would refract the pencil of rays shown in Fig. 34 just as readily as it would refract that of Fig. 35 after refraction from the cover-glass as shown in the figure, and in both cases the pencil would be brought to the same focus behind the objective.

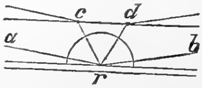
"Let us now put x = each degree of angular pencil from the radiant. Then in Fig. 34 the objective will take in a pencil of $\overline{170\,x}|^2$; but as the radiant pencil in Fig. 35 is only 80°, diluted on emerging from the glass cover, in that case the objective will only take in a pencil of $\overline{80\,x}|^2$; it is therefore clear that the one is not the 'optical equivalent' of the other.

"The comparison of a pencil *after refraction* with one in its original condition, when the question under discussion is one solely as to the size of pencil direct from the radiant, has no bearing upon the point at issue. If compared after one refraction, why not after any number of them?

"If two pencils of 20° each—radiant from points in air—fall, one on a concave lens which it exactly fills and refracts so that on emergence it is diluted into a pencil of 40°, and the other similarly falls on a convex lens which refracts it so that it is compressed into an angle of only 10°, their angular *aperture* is not changed by the fact of their subsequent dilution or condensation—they are still both of 20° aperture.

"In order to bring the radiant in Fig. 34 into the same condition as that in Fig. 35, it would be necessary to cover the former with a slip of glass having a semi-globular cavity on its under side, and so placed that the radiant point is in the centre of the cavity as in the annexed diagram, Fig. 110, which upon the 'optical equivalent' theory involves the assertion, that the angle *c*, *r*, *d* is equal to the angle *a*, *r*, *b*.

FIG. 110.



"I understand now that it is contended that the radiant pencil *c*, *r*, *d* in balsam, that is 80° angular, emits as much light *under a given illumination* as the angle *a*, *r*, *d* in air, 170° angular. I have not, until after the last meeting of the Society, imagined that any such assumption was in existence. I stated as much in my previous communication; I am yet without a shadow of proof of its accuracy—it may be my fault or my misfortune—but even if proved to be true, I submit that the term 'aperture' to express the difference is inappropriate, to say the least."

Mr. Crisp said * that (1) Mr. Shadbolt had unnecessarily complicated his own view of the matter by introducing the concave hemisphere. All he need have done was to take Figs. 34 and 35 and point out that the 170° in air in the two cases could not, on his view, be equivalent, inasmuch as one originated from a pencil of

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* This note also was taken as read.

80° at the radiant, while the other was 170° at the radiant. As a small part could not equal a greater part of the same whole, Mr. Shadbolt's contention was established in a simple manner without the hemisphere, always supposing that the assumption with which he started was correct.

Unfortunately, as the further Note showed, Mr. Shadbolt was still involved in exactly the same fallacy as at the December and January meetings, viz. first, that the aperture question could be rested on the basis of photometry simply, and secondly, that radiation in air and radiation in balsam were the same things. On this supposition, he (Mr. Shadbolt) of course could not regard the small balsam-pencil of 80° in Fig. 35 as the equivalent of the large air-pencil of 170° in Fig. 34; but treating the former as *less*, it necessarily followed that when expanded into 170° after refraction it still was less (or was "diluted") in comparison with the original unrefracted pencil of 170°. It was indeed diluted, but what Mr. Shadbolt had failed to grasp was that it was first equally "compressed" (using his expression), so that "compression" and "dilution" balancing one another, the pencil, notwithstanding refraction, *did* contain the same amount of light as the unrefracted pencil. It was singular that Mr. Shadbolt had not seen the inadequacy of such a photometrical test of aperture, even if he had been right in his application of it, but if he insisted on its adequacy the first step he must necessarily take was to get rid of the notion that the small balsam-pencil of 80° in Fig. 35 did not contain the same amount of light as the large air-pencil in Fig. 34.

(2) In the next place, Mr. Shadbolt suggested that "nothing had been shown to disprove the view he enunciated" as to aperture.

Now, Mr. Shadbolt had formulated his conclusions in his original paper in such unusually emphatic words as these:—"*I have therefore demonstrated beyond dispute that,*" &c.; and his demonstration was based on two things: (1) a diagram, and (2) a photometrical proposition.

As to the *diagram*, that was disposed of by one of the simplest and most elementary of optical considerations (see p. 334), which had been entirely overlooked by Mr. Shadbolt; and not only so, but it was further shown that no *other* diagram could be drawn in support of his view, unless an angle were found whose sine was greater than 1! The diagram was in fact another of those curious instances which had so often occurred in the angular-aperture discussion, of its supporters being so certain that their view *must* be right, that it never occurred to them to test the proof which they supposed they had given, by an apparatus which was in the possession of every one, and which was so simple and free from complication as a plano-convex lens!

On the *photometrical* question, Mr. Shadbolt himself rested his view on the equivalence of radiation, no matter what the medium was; and his whole argument from first to last could only hold good on the supposition that that view was correct, as he himself admitted with perfect candour. Leaving out of account any comment upon the strangeness of basing the aperture question solely on quantity of light, the difficulty in supporting the second point was, however, of the same kind as prevented the discovery of the angle with a sine greater than 1 !

What, therefore, Mr. Shadbolt could intend by the sentence that "nothing had been shown to disprove his view," it was difficult to say, not a single shred of his demonstration having been left standing, and nothing remained but the words, "I have *therefore* demonstrated beyond dispute," &c. !

(3) A remark must also be made as to the last sentence of Mr. Shadbolt's note, in which he suggested that even if his view of radiation turned out to be incorrect, it did not affect the discussion! Now he (Mr. Crisp) had no desire to press unduly upon Mr. Shadbolt personally, but it was obviously impossible, under the special circumstances of the case, to allow that to pass. Mr. Shadbolt, having an unlimited range of selection, and being absolutely free to choose his own ground, deliberately selected the photometrical question on which to rest his claim to have "demonstrated beyond dispute" that his view of the aperture question was the correct one—a demonstration, which was not couched in the usual style of scientific papers, but in regard to which a course was adopted (happily exceptional in these days) of railing in advance at the supposed absurdity of a scientific theory, admittedly without having first made any endeavour to ascertain the grounds on which it had been accepted—a paper, moreover, in which it had been attempted to hold up to ridicule the editors of the Journal, and the "authorities" of the Society, for their inability to understand the extremely simple explanation which Mr. Shadbolt, in all seriousness, supposed to dispose of the whole matter.

When it turned out that it was not they but Mr. Shadbolt himself who had overlooked (in fact was actually not aware of) the fundamental optical principle which upset his demonstration, he must not simply turn round and suggest that it made no difference whether it was right or wrong. If it was wrong, the editors and the "authorities" were of course not so much to blame after all for not having understood it or adopted it, and they were entitled to have that point properly disposed of and not slurred over before passing to another.

In the remarks which he (Mr. Crisp) had made, he need hardly say that he was acting simply on the *defensive*, and was only concerned in repelling, not on his own behalf, but in the interest of the Society itself, the suggestion which Mr. Shadbolt had made of, what he evidently honestly believed to be, a gross state of ignorance on the part of the "authorities" of the Society. A merely *tu quoque* retort would be in every way out of place; for at the time when Mr. Shadbolt was President—now twenty-five years ago—microscopical optics was in its infancy. The Lambert-Bouguer law of radiation in one and the same medium, though older than the century, had not then been appreciated by microscopists—the principle of increased radiation in denser media than air had no practical interest in microscopy, as at that time immersion glasses had not found their way into England—while, further, all microscopical optical problems were treated, in accordance with the optical literature of the day, as referring to infinitesimal pencils only, and the action of wide pencils, although of course *the* important point for the Microscope, was left unconsidered. It would obviously therefore be ungracious for those whose optical education had happened to fall upon more enlightened times, to depreciate others who, whilst having had an equal *will* for learning, had undoubtedly had much less *opportunity.*

What, however, he (Mr. Crisp) had said as to the necessity for clearing one point before passing to another, equally of course applied even if—as Mr. Shadbolt put it, and as every one would be very ready to believe—it was not by his "fault" but only by "misfortune" that he had fallen into his mistake.

Professor Abbe's paper "On the Estimation of Aperture in the Microscope" was taken as read.

The President announced that the second "Scientific Evening" of the Session had been arranged to be held on the 20th April.

The following Instruments, Objects, &c., were exhibited:—

Mr. Crisp:—(1) Abbe's Radiation Apparatus for demonstrating the increased radiation of light in balsam and glass as compared with air (see p. 343). (2) The Griffith Club Portable Microscope (see p. 293). (3) Murray and Heath's Polarizing Apparatus (see p. 302). (4) Slide for showing that the aperture of an objective is not "cut down" by a balsam-mounted object, but remains the same as on a dry object.

Mr. Curties:—An Amici Reflecting Microscope.

Mr. Michael:—*Dermaleichus heteropus.*

Mr. Reed:—Stained section of embryo of Mistletoe.

New Fellows:—The following were elected *Ordinary* Fellows:—Messrs. A. A. Bragdon, R. T. Burnett, H. C. Luck, F.R.G.S., W. Rideout, D. G. Simpson, and W. G. Tacey, L.S.A.

WALTER W. REEVES,
Assist.-Secretary.

The Journal is issued on the second Wednesday of February,
April, June, August, October, and December.

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Vol. I. Part 3.

JUNE, 1881.

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JOURNAL

OF THE

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AND A SUMMARY OF CURRENT RESEARCHES RELATING TO

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(Principally Invertebrata and Cryptogamia),
MICROSCOPY, &c.

Edited by
FRANK CRISP, LL.B., B.A., F.L.S.,
One of the Secretaries of the Society;

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE, AND OF

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Lecturer on Botany at St. Thomas's Hospital,

F. JEFFREY BELL, M.A.,
Professor of Comparative Anatomy in King's College,

S. O. RIDLEY, M.A., *of the British Museum*, AND JOHN MAYALL, JUN.,
FELLOWS OF THE SOCIETY.

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(JUNE.)

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	„	MARCH	9
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	„	DECEMBER	14

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See Journal of the Society, I. (1881) pp. 548-9.

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☞ *A special feature of the Journal is the classified Summary it contains of the work of British and Foreign Observers relating to Zoology and Botany (principally Invertebrata and Cryptogamia), Microscopy, &c., as appearing in the principal Journals, Transactions, &c., of this and other Countries.*

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The Journal comprises:

(1.) The TRANSACTIONS and the PROCEEDINGS of the Society: being the Papers read and Reports of the business transacted, at the Meetings of the Society, including any observations or discussions on the subjects brought forward.

(2.) SUMMARY of CURRENT RESEARCHES relating to ZOOLOGY and BOTANY (principally Invertebrata and Cryptogamia, with the Embryology and Histology of the higher Animals and Plants), and Microscopy (properly so called): being abstracts of or extracts from the more important of the articles contained in the various British and Foreign Journals, Transactions, &c., from time to time added to the Library, so far as they relate to the above subjects.

Authors of Papers printed in the Transactions are entitled to 20 copies of their communications *gratis*. Extra copies can be had at the price of 12*s.* 6*d.* per half-sheet of 8 pages, or less, including cover, for a minimum number of 100 copies, and 6*s.* per 100 plates, if plain. Prepayment by P.O.O. is requested.

All communications as to the Journal should be addressed to the Editor, Royal Microscopical Society, King's College, Strand, W.C.

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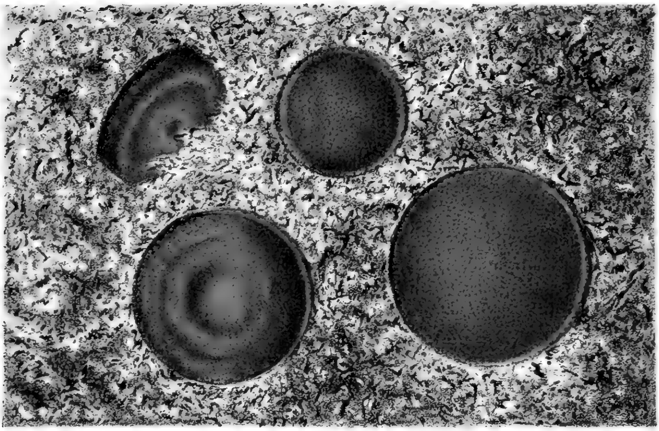
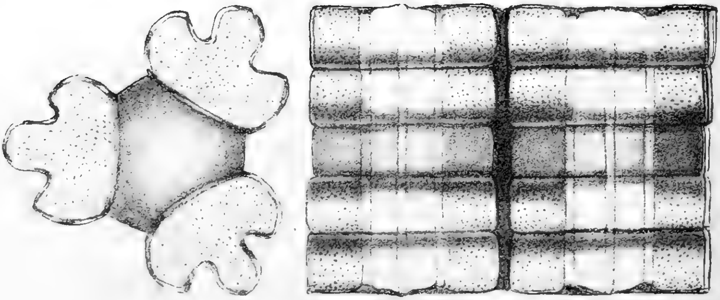
1.



Diatoms of the London Clay.

3. 2.



Hydrosera tricoronata.

M. Heeks lith.

West Newman & C^o imp.

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TRANSACTIONS OF THE SOCIETY.

VI.—*The Diatoms of the London Clay.* By W. H. Shrubsole, F.G.S. *With a List of Species, and Remarks.* By F. Kitton, Hon. F.R.M.S.

(*Read 13th April*, 1881.)

Plate V., Fig. 1.

In 1877–8 I carefully watched the sinking of a well at Sheerness, and embodied the results of my observations in a paper published in the 'Proceedings of the Geologists' Association,' vol. v. p. 355.

One day, when examining clay from the shaft, I noticed some forms which I afterwards ascertained were Foraminifera, and being desirous of finding more species of that group, the possibility of meeting with other microscopical organisms did not occur to me. When, therefore, I saw in the clay at a subsequent period, small disks, apparently of pyrites, I noted the fact, but did not examine them further. Being familiar with the manifold forms in which pyrites occurs in the London clay, I concluded that these disks were but concretions of that mineral on a small scale.

In the paper referred to, I described them as "*very minute disks of iron pyrites, each having a boss in the centre, and having the edge slightly turned up all round. They were perfectly uniform* (by a mistake, the words were printed 'uniformly perfect'), *as much so as if cast in one mould*," and it is strange, therefore, that some one acquainted with diatoms (which at that time I was not) did not point out that the description given would in some respects apply to many of the discoidal forms of the Diatomaceæ.

Subsequently, after I had found diatoms in the sand and mud along the coast of Sheppey and elsewhere, I repeatedly examined the London clay in the hope of finding kindred forms, always

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EXPLANATION OF PLATE V., Fig. 1.

Fig. 1.—London clay with diatoms *in situ* (from a drawing by Mr. A. Hammond, F.L.S.) × about 100.

looking for them as the lightest particles, and it need scarcely be said, always in vain.

In 1879, Dr. Bossey, F.R.M.S., of Redhill, to whom I am greatly indebted for assistance in the study of diatoms, encouraged me to renew the search: and I again examined samples of London clay from various localities, and from the whole length of the Sheppey cliffs. This I did by drying the clay, mixing it with water, and then looking for the diatoms on the surface, but none were seen.

I was one evening looking for the first time at a slide of *Aulacodiscus Oreganus*, when the thought struck me that the metallic specks noticed in 1877, and almost forgotten, were the very things I was in search of. I quickly turned out all the samples of clay from the Sheerness well that I had preserved; but no diatoms were visible. I then disintegrated and washed some from about the same depth as that at which the metallic specks had been seen, and after several failures I ultimately, on December 1st, 1879, found the shining disks that had previously attracted my attention.

Bearing in mind that the objects were evidently mineralized, and therefore heavier than the fine particles of clay, I got rid of as much of the clay as possible, and found that the residuum consisted almost entirely of the mineralized forms more or less entire, and in some cases aggregated in small masses.

I had in my possession a complete set of specimens of clay taken from a well in Sheerness dockyard in 1812, and these I broke up that I might ascertain if the diatoms occurred in that well at the same or at any other depth. The result was that I found them, but only at about the same horizon as those in the Town well. I then subjected to close examination clay from a boring close to the old "King's Well" (which was commenced in 1781, and was the first well that pierced the London clay in the Isle of Sheppey), and found the diatoms still at the same level.

Finding them thus in three wells some distance apart, I suspected that, although limited to one zone, there was probably a considerable lateral extension of the diatomaceous band. To test the correctness of this conclusion, I went to Herne Bay, and going eastward from the town along the beach, examined the clay at intervals, which, owing to the inclination of the beds, represented a considerable vertical thickness. Near Oldhaven Gap, the basement bed of the London clay crops out. Just before getting to this spot, on splitting open a clod to get an unweathered surface, and using a lens, I was much gratified by finding the diatoms. Further examination showed that they occur in irregular patches, which had helped to produce the slight lamination observable in the clay there.

At Upnor, as is well known, the junction of the London clay with the beds below is clearly shown in the most easterly pit. Here also, after some failures owing to hard frost, I found diatoms of the same species, in the same condition, and at the same geological level as at Herne Bay and Sheerness. I went next to the Loam Pit brickyard at Lewisham, and was rewarded with equal success. At this place I learned from the workmen that when digging out the clay they frequently observed "shining spots" in it.

Guided by the valuable 'Memoir of the London Basin,' Part 1, by W. Whitaker, Esq., F.G.S., I visited several other localities. In several cases I found that the sections accurately described ten years before, were overgrown, or that the sites where such had been were then built upon. On going to Bishop's Stortford, however, on the same errand, I gathered information which convinced me that the diatoms are to be found in well sections in that locality.

Interviews with Messrs. Docwra and Sons, Messrs. Le Grand and Sutcliff, Mr. T. Tilley, and other prominent well-sinkers, who very kindly gave me all the assistance in their power, put me in possession of the knowledge that all round London, and indeed almost anywhere in the London basin, clay appearing as if it had been dusted with powdered sulphur, and sparkling in sunlight, had long been noticed whenever wells had been sunk within the indicated area.

In a well in progress at Prittlewell for increasing the water supply of Southend, no diatoms were found until the depth of 360 feet from the surface (equal to 260 feet below Ordnance datum) was reached. Much of the clay taken out down to 366 feet from the surface was very rich.

Dr. Bossey was the first to discover that besides the solid, heavy forms, there were some that had not been so completely mineralized, and would bear examination with high powers by transmitted light; and to guide others in separating these transparent forms, Dr. Bossey has kindly given the following directions:—"Dry the clay, and put it into a tall glass jar half full of water. Shake it gently, let it stand three or four minutes, and then pour off the thin portion. Repeat this process as long as a turbid milky fluid can be poured off. In thus washing away the lighter matter, always leave an inch or two of water above the sediment. When the sediment has been well washed, pour some fresh water into the jar, and very quickly pour off the turbid fluid, leaving only coarse sand, lumps of clay, &c. Repeat this process three or four times, and collect all that has been washed over, and set it aside till everything has subsided from it. Pour off nearly all the water from this sediment (which contains the diatoms), and put the sediment with a little water into a watch-glass. Blow air through a pipette into the watch-glass, so as to set the whole of the contents whirling round the watch-glass. While the fluid is still in motion, put the point of the pipette into the cone of floating matter which will be found in the centre of the glass, and draw up some of the water with such particles as will rise with it. Blow this out of the pipette on to a slide or into another watch-glass, and dry off the water. The partially transparent diatoms will be found chiefly on the surface."

These light forms are not nearly so abundant as the more thoroughly mineralized ones, and are not always to be found in clay containing the others.

With the diatoms were found Sponge spicules, Xanthidia, Radiolaria, internal casts of Foraminifera,[*] and some interesting forms whose affinity has not yet been determined.

From various considerations that need not be stated, there is little doubt that these diatoms existed continuously throughout the London clay period. Yet, as far as my own observations have gone, and from what I have learned from others, no trace of them is found except as having existed in the early part of that period.

I trust that the absence of diatoms, either mineralized or in the ordinary siliceous condition, from the whole of the London clay above the zone referred to, will be satisfactorily accounted for. I can only indicate the problem that awaits solution.

Among the large number of letters respecting these diatoms that have reached me from nearly all parts of the world, perhaps one from Count Castracane is the most interesting, and I therefore append an extract from it:—

"You could not have given me a greater pleasure than sending a sample, and giving me notice of your most interesting discovery of a deposit of diatoms belonging to the Lower Eocene. But the appearance of these diatoms is so novel, that I preferred first to make a careful study of them before giving any description. I must confess that at the first examination I could not persuade myself that a powder like this, dark and heavy, and with parts of metallic lustre, could really contain diatoms. The great number of diatomaceous deposits known to us, always appear as a white, light material, and the specimens are transparent. I dare say that I am not mistaken in saying that you have been the first to discover diatoms, not only fossil, but mineralized, in which the organic parts are found replaced completely (atom by atom) by pyrites. This latter substance has been deposited by an electro-chemical process so as to form the impression. To be able to prove this point, it might be of some advantage to examine the matrix with the diatoms *in situ*, and therefore you will much oblige me by sending some of the clay containing them. It will also be interesting to ascertain if the same types of diatoms in the condition of silicon are to be met with in the same stratum, or in the next formation to it. Also, if they are to be found living in the water of the neighbourhood. I

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[*] At higher levels in the clay where the diatoms are not found, entire shells of Foraminifera, partially or quite filled with pyrites, are plentiful.

am quite sure that since you have found diatoms in the Lower Eocene, and I in the carboniferous rocks, geologists will now expect to find them preserved in other and older formations, and that they will be obliged to confirm my observation that in the order of the Diatomaceæ the species remain constant in their characters."

As a result of many experiments, my opinion is that in a certain proportion of the diatoms the pseudomorphic process has not been completed. On this point Dr. Bossey says, "I fully concur with you in the belief that the silica in some cases remains."

Remarks on the above Paper, with a List of the Genera.

By F. Kitton, Hon. F.R.M.S.

In the month of December, 1879, I received a letter from Mr. Shrubsole, asking me to give my opinion of some minute disks (supposed by him to be diatoms), which he said I should find in the material sent for examination, and which he informed me was obtained by washing the London clay. I carefully examined with a $\frac{1}{4}$ objective many trial dips of the lightest parts of these cleanings, but saw no trace of diatoms (excepting a recent frustule or two of *Melosira moniliformis*, introduced by accident). As I was not at that time aware that diatoms had been found in a mineralized condition, I did not examine the heavy dark-looking debris, which subsided so rapidly, and appeared so unlike any diatomaceous material with which I was acquainted. I therefore wrote to Mr. Shrubsole, informing him of my non-success.

In his third communication he gave me the clue which enabled me to detect the character of these discoidal bodies, and I was surprised and delighted to find that they were undoubtedly diatoms, but in a state so totally unlike any other fossil diatomaceous deposit, that any diatomist might be pardoned for not detecting them. I at once wrote to him, congratulating him on his discovery. I have since then received many samples of crude and cleaned material, which has enabled me to identify the genera, and in some instances the species, to which the diatoms belong.

The first form I found was a *Coscinodiscus*. It was of a dark bronze colour, and when examined as an opaque object with $\frac{2}{3}$ objective and Lieberkühn, the cellulation was distinctly visible. A further search in the material (this was from the Sheerness well) afforded many specimens, both perfect and fragmentary, of at least two species of *Coscinodisci*, all of them being frustules. In samples from other localities I found mixed with the frustules many perfect valves, the outer surface of which were of the dark bronze colour before mentioned, the inner surface having a brilliant golden appearance, exhibiting all the lustre of a highly polished gold plate, upon which, radiating from the dark central umbilicus, a series of black dots were very distinctly visible. These valves, when mounted in balsam, became partially transparent; the umbilicus and dots were evidently openings or perforations in the valve; the solid metallic framework was thin enough in some cases to allow the light to pass through it, giving the diatom the aspect of a dark indigo-coloured disk with distant minute apertures.

This metallic appearance is undoubtedly caused either by the deposition of iron pyrites (ferric bisulphide) upon the siliceous skeleton, or it has replaced atom by atom the original silica of the diatom frustule. I was at first inclined to the former supposition, and which the appearance of the valve seemed to confirm; the lustreless somewhat granular character of the exterior and the smooth polished interior surfaces forcibly reminding one of the electro-galvanic deposition of metals. Acting on this supposition, I thought it might be possible to divest the silica of its metallic coating, and thus be able to ascertain the species with greater certainty. To effect this, I submitted some of the material to the action of boiling nitric acid. This very effectually removed the pyrites, and was equally effectual in the destruction of the diatom. Supposing that this treatment was too violent, I placed some valves and frustules in an excavated slide with some very dilute acid, and placed over them a thin cover-glass, and watched the action under a $\frac{2}{3}$ objective. In the course of a short time I saw the valves become more and more transparent, and at last disappear, leaving only a faint yellow stain in the acidulated water. I may here observe that I could detect no symptom of effervescence upon the surface or around the edges of the valves or frustules. This experiment, I think, fully justifies the supposition that the silica has been replaced by, rather than that a deposit of pyrites had taken place.*

The way in which this substitution of one substance for another takes place has, I believe, never been explained.

I have occasionally observed, both on the outer and inner surfaces of the valves, a curious deposit of small globules of pyrites, resembling minute (about $\frac{1}{2000}$ of an inch in diameter) pewter balls or marbles.

One of the samples (I think that from Prittlewell) was very rich in diatoms, most of which were in a highly pyritized condition, so much so that the markings are often but indistinctly visible. On submitting them to the action of dilute nitric acid, the diatoms slowly dissolved, but did not become transparent.

Although I have made a careful search in the London clay for diatoms in their original state, I have not succeeded in finding them. In the lightest portions I occasionally find minute frag-

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* I have tried the same experiment upon the pyritized sponge spicules and fragments of wood associated with the diatoms and in the same condition, with a similar result.

ments of *Coscinodisci* more or less transparent, but they disappear when acidized.

The diatoms in the London clay are probably contemporaneous with those found by Ehrenberg in marl from Ægina, and are therefore the oldest fossil remains of these organisms. (Their occurrence in the chalk, as stated by Ehrenberg, is undoubtedly erroneous. The few forms figured by him are from fresh water, and probably quite recent.*)

The following list comprises all the forms hitherto detected in London clay:—

Arachnoidiscus Ehrenbergii (? ?)	Very rare.
Actinoptychus (*Actinophœnia*) *splendens*	One valve only.
Coscinodiscus perforatus (?)	Common.
,, *radiatus* (?)	Frequent.
,, *robustus* (?)	Rare.
,, *subtilis* (?)	,,
,, *minor* (?)	Frequent.
Craspedodiscus (?)	One valve only.
Pyxidicula	Rare.
Trinacria regina	Small fam., common in the Prittlewell gathering.
Triceratium alternans	One valve only.
,, *favus*	,, ,,
,, *acutum* (?).	
Solium exsculptum	Rare.
Corinna elegans (?)	,,
Hemiaulus hostilis (?)	,,
Eupodiscus Argus (? ?)	,,
Synedra (? ?).	

Forms found by Dr. Bossey (those with * named by Mr. Kitton from sketches by Dr. Bossey).

Triceratium (4 species).
* ,, *dubium.*
Trinacria regina.
**Coscinodiscus symmetricus.*
Corinna elegans.
**Pyxilla* sp. (?).
Hemiaulus polycystinorum.

**Xanthiopyxis* sp. (?).
Arachnoidiscus.
Craspedodiscus (? ?).
**Stictodiscus* (?).
**Biddulphia elegantula* (?).
* ,, ,,
**Terpsinöe* on *Biddulphia.*

By Dr. Stolterfoth, M.A., &c., Chester.

Trinacria excavata. *Hemiaulus* (*antarcticus*). *Eupodiscus Argus.*

By Mr. G. D. Brown, Ealing.

Biddulphia aurita. *Synedra* (?) on *Nitzschia* (?). *Triceratium* (?) sp. (?).

By Mr. Shrubsole.

Liostephania rotula (one specimen only) and most of the above species.

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* Although there is no satisfactory evidence of diatoms ever having been found in the chalk, their existence in the Cretaceous period is extremely probable. And if Mr. Sollas' suggestion (Rep. Brit. Assoc., 1879, p. 350), that the silica of certain siliceous sponges has been replaced by lime is correct, we have a clue to the absence of diatoms in the chalk, the carbonate of lime having in like manner replaced the silica of the diatom valve.

VII.—*On the Estimation of Aperture in the Microscope.*

By Professor E. Abbe, Hon. F.R.M.S.[†]

(*Read 9th March*, 1881.)

In originating the "*numerical*" definition of aperture, my special aim was to signalize the all-important fact, so long overlooked and even denied, of the existence of an *unequal equivalent of equal aperture-angles in different media;* to propound a simple and exact expression by means of which this unequal equivalent could be estimated; and thus to afford a definition of aperture for the practical comparison of objectives, which should exhibit the true relation of aperture to the *actual performance* of the Microscope, a relation which is entirely concealed by the *angular* expression.

As some little time must probably still elapse before my more extensive paper "On the Function of Aperture in Microscopical Vision" can be completely printed (a great part of which was laid before the Meeting of the Society in June 1880[‡]), it has been suggested to me that it may be useful if I here summarize the principal considerations which bear upon the determination of the aperture-equivalent in the Microscope.

I.—*Definition of Aperture by the Ratio of "Opening" and Power.*

The general notion of "aperture," which every one forms *prior* to attempting any distinct definition of the term, unquestionably refers to the greater or less number of rays which are collected and utilized by an optical instrument—consequently, to the *opening* of the lenses or lens-systems, and to that alone. Every definition of the term must conform to this primary idea.

In the case of a telescope-objective the *absolute* opening of the lens is itself the proper expression of aperture; because in the depiction of *distant* objects by parallel (or approximately parallel) rays, no other element can have any influence on the larger or smaller number of rays admitted from an object at a definite distance. This is a matter of general agreement.

If we consider the case of the Microscope, however, the matter is not quite so simple.

(1) In a *single*-lens Microscope it is evident that the number of rays admitted within one meridional *plane* of the lens increases in the proportion of its clear diameter, provided all other circumstances are the same. For if the lens projects a distinct image to a

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[†] The original paper is written by Prof. Abbe in English.—Ed.

[‡] See this Journal, iii. (1880) p. 735.

distance which is great in comparison with its diameter—as is always the case in the Microscope—we have *at the back* of the lens the same circumstances as are *in front* when a telescope-objective is considered. Consequently, the larger or smaller number of *emergent* rays will be properly measured by the clear diameter; and as no rays can emerge which have not been taken in, this estimation must apply at the same time to the *admitted* rays,—other circumstances, in particular the distance of the radiant from the lens, being equal.

The question, however, will now arise, how is the difference of these *other* circumstances on the microscope-lens to be taken into account?

A simple consideration shows at once that this is properly done by taking the *absolute* diameter of the lens (or its "opening") *in proportion to the focal length.* When two lenses have equal openings but different focal lengths, they transmit the same number of rays to equal areas of an image at a definite distance, because they would *admit* the same number if an object were substituted for the image, that is if the lens were used as a telescope-objective. But as the focal lengths are different, the amplification of the images is different also, and equal areas of these images correspond to different areas of the object, *from* which the rays are collected. Therefore the higher-power lens with the same opening as the lower power, will admit a *greater* number of rays in all from one and the same object, because it admits the *same* number as the latter from a *smaller* portion of the object. Thus if the focal lengths of two lenses are as 2 : 1, and one of them amplifies an object N diameters, the other of shorter focal length will amplify the object 2 N diameters with the same distance of the image. Consequently the rays, which in both cases are collected *to* a given field, say of 1 mm. diameter, of the image, are admitted *from* a field of $\frac{1}{N}$ mm. in the first case, and of $\frac{1}{2N}$ mm. in the second. If now the idea of aperture referred to the photometrical *quantity of light,* the capacities of equal openings with different focal lengths would of course be in the inverse ratio of the *areas* from which equal quantities are admitted, and would then be in the direct ratio of the *squares* of amplification. Inasmuch, however, as the *opening* is estimated by the diameter and not by the area, the consideration is confined to the rays which travel within one meridional *plane* of the lens, and the same principle must be applied to the *fields* from which the rays are admitted; which must also be estimated by their *diameters.* The higher-power lens in the example given above therefore admits *twice* as many rays as the lower power, because it admits the *same* number from a field of *half the diameter*; and, in general, the admission of rays with different focal lengths (the opening being the same) must be in the inverse ratio of the focal lengths.

In a single-lens Microscope, aperture must be determined, therefore, by the *ratio between the clear opening and the focal length of the lens*, in order to define the *same* thing, as is denoted in the telescope by the *absolute opening*.

(2) Regarding now *composite* systems—the most important case in the Microscope—the further question arises, what is the opening of *such* a system? The actual opening, which limits physically the transmission of the light through a composite objective, varies according to particular circumstances. It may be the margin of the front lens, or of any one of the posterior lenses, or it may be a diaphragm inserted in some part of the system. As the cone of admitted rays expands continuously from the radiant up to the back lens, the same objective admits of innumerable different openings of this kind, which nevertheless may indicate the same aperture, and thus no definite opening could be assigned. This ambiguity cannot be removed unless we adhere to the diameter of the admitted cone at that plane where it has its *ultimate maximal* value, which is obviously the diameter of the pencil at its emergence from the system, or, practically, the *clear effective diameter of the back lens.* The emergent pencil from a microscope-objective, converging to a relatively distant focus, has its rays approximately parallel, and the conditions are once more similar to those of the telescope-objective on the side of the object. The diameter of this emergent pencil, whether it emerges from a single lens or from a composite system, must therefore always have the same signification.

The influence of the power or focal length also remains the same as in the case of the single lens. An objective with a focal length equal to half that of another admits with the same linear opening twice as many rays as the latter, because the amplification of the image at one and the same distance is doubled, and the same number of rays, consequently, are admitted by the higher power from a field of half the diameter. *This must hold good, whether the medium at the object is the same in the case of both objectives, or different.* For an immersion system and a dry system always give the *same* amplification when the focal length is the same.

Thus we have as general propositions for all kinds of objectives: (*a*) the admission of the rays with one and the same power or focal length varies with the linear diameter of the pencil at its emergence; (*b*) with different powers, the *same* admission requires different linear openings in the proportion of the focal lengths—or conversely, the admission by one and the same opening is in *inverse* proportion to the focal length. *Consequently the aperture of an objective is always exhibited by the ratio between the linear* *opening (at the plane of emergence) and the focal length of the system.*

There is no other rational way of defining the admission of rays to an objective, and consequently no other definition of aperture which agrees with this fundamental idea. I need hardly say that this suggestion is nothing *new*. It is a matter of general consciousness; for every one will agree that the aperture of a given objective is altered when the utilized diameter of the back lens is changed by the application of different stops; and that a clear opening of say 3 mm. in a $\frac{1}{4}$, is *less aperture* than the same clear opening in an $\frac{1}{8}$.

On the other hand, it is true that the apertures of objectives may be compared *as regards equality or inequality merely* by the angles of the admitted pencils, if the medium at the radiant is the same, because *under this condition* equal angles indicate an equal admission of rays, and different angles different admission. The assumption, however, that *apertures* can be defined or compared by the angle *alone,* is an entirely arbitrary one unless it were proved that the admission of rays is always in proportion to the angle, and does not depend on any other element. As no attempt at a proof has been brought forward in support of this hypothesis (it being in reality, as will be seen hereafter, opposed to the fact), the proper way of obtaining a correct expression of aperture *by means of the angle* will be to investigate *what* expression must be taken, in order to define the same thing as is denoted by the ratio of opening and focal length.

Until a comparatively recent period the above assumption has persisted as a dogma—without any investigation of the subject. The author may claim to have been the first to put this dogma to the test of scientific principles and to point out its fallacy by the indication of the *unequal* aperture-equivalent of objectives.

The demonstration of the *general* validity of this fact is given here in detail for the benefit of those who may care for such a treatment of the question.

II.—*Determination of the relative Openings of Systems by the Aperture-angle and the Refractive Index of the Medium.*

In 1873 the author and—quite independently—Professor Helmholtz established a general relation between the pencil of rays *admitted* by an optical system and the pencil *emerging* from it; a relation which pertains to the angles of convergence in both pencils, and must always obtain whenever a system is *aplanatic,* or is capable of depicting an object by means of wide-angled pencils. The proposition is:—

Let O and O* (Fig. 111) be the conjugate aplanatic foci of a wide-angled system; u, U the angles of inclination of *any two* rays admitted from the radiant, and u^*, U^* the angles of the same rays on their emergence; then we shall have always

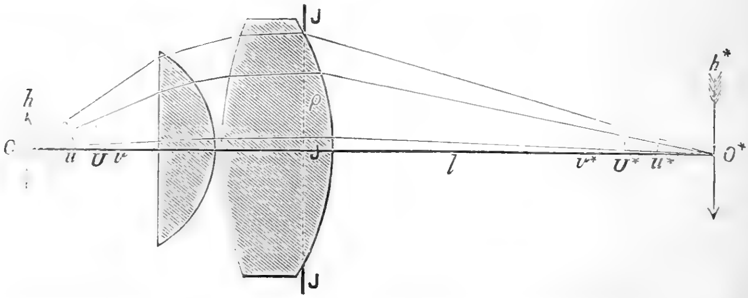
$$\sin U^* : \sin u^* :: \sin U : \sin u;$$

or

$$\frac{\sin U^*}{\sin U} = \frac{\sin u^*}{\sin u} = \text{const} = c; \qquad (1)$$

i.e. the *sines* of the angles of conjugate rays on both sides of an aplanatic system always yield one and the same quotient c, whatever rays may be considered, as long as the same system and the same foci are in question.

Fig. 111.



This proposition holds good for every composition of the system (every arrangement of media and refracting surfaces), and for every position of object and image. In point of fact, the *law of convergence for aplanatic systems*, as indicated above, is the *necessary* condition (physically and geometrically) on which depends the delineation of an image by means of wide-angled pencils. When in any case the convergence of the rays in a system of lenses is not in accordance with this condition (very approximately at least) that system will be unfit for depicting an image of an object, except by *narrow*-angled pencils.

Microscope-objectives *do* of course depict images with wide-angled pencils, and consequently the proposition must apply to them without any restriction; the author, it will be remembered, has suggested a simple experiment † by which every one may satisfy himself that all such objectives, if moderately well made, are in perfect accordance with this statement.

Suppose now, that for any particular objective and any particular position of the conjugate foci of object and image, the value of the constant quotient c of formula (1) is determined numerically, in any way whatever; it will then be possible to compute the

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† See this Journal, iii. (1880) p. 511.

obliquity u^* of *any* emergent ray from the obliquity u of the same ray at its entrance, by means of the equation

$$\sin u^* = c \sin u\,; \tag{2}$$

and if this equation is applied to the ray of *utmost* obliquity which is transmitted through the system, u^* will express the semi-angle of the emergent pencil, whilst u is the semi-angle of the admitted cone of light or the *semi-angle of aperture.*

The *linear* opening of the system, or the diameter of the delineating pencil at the plane of its emergence, is readily calculated by means of the angle u^* and the distance at which the image is projected. If J is the plane of emergence (the plane of the back surface of the system) and l the distance of the image from J, the linear *semi*-diameter ρ of the pencil is, obviously,

$$\rho = l \tan u^*,$$

for which may be substituted the identical equation

$$\rho = l \frac{\sin u^*}{\cos u^*}.$$

In the case of microscope-objectives, the distance l (the length of the microscope-tube) is always many times greater than ρ, and accordingly the angle of convergence u^* is always very small, never exceeding a few degrees. The *cosine* of such an angle may be put $= 1$ without appreciable error; and taking now the value of *sin* u^* from the equation (2) we obtain

$$\rho = c\, l \sin u, \tag{3}$$

which expresses the linear semi-aperture of the system by the semi-angle of aperture.

The question will now arise: how is the value of c for every particular case to be obtained?

This is established by a dioptrical proposition of older date, which is known as the Lagrange-Helmholtz law of convergence of *infinitesimally narrow* pencils. If O and O* denote conjugate foci, h the diameter of an object at O, and h^* the diameter of its image at O*, n and n^* the refractive indices of the media in front and at the back of the system, whilst v and v^* are the angles of obliquity of any ray traversing the system *close to the axis,* then we have always

$$\frac{v^*}{v} = \frac{n}{n^*} \cdot \frac{h}{h^*}; \text{ or} = \frac{n}{n^*} \cdot \frac{1}{\mathrm{N}}, \tag{4}$$

where N denotes the linear amplification of the system for that pair of conjugate foci; and this holds good for every composition of the system and for every position of the conjugate foci. According to this proposition, the ratio of infinitesimal angles v and v^* (pertaining to one and the same ray at its entrance and emergence) may be completely determined by the refractive indices of the media at the radiant and at the image and by the linear amplification of the image, *without regard to the elements of the optical system or to the position of the foci.*

This important theorem was established by Professor Helmholtz in 1866.† Its earliest origin must be traced back to Lagrange, who pointed out a similar proposition, confined however to less general conditions, in 1803.‡

The way in which equation (4) leads to a general determination of the constant c, which appears in the law of convergence of *wide*-angled pencils, will be readily understood. Any wide-angled cone of rays admitted to an aplanatic system, embraces axial rays of infinitesimal obliquities v and v^*, and as in the case of very small angles the ratio of the *sines* becomes identical with the ratio of the angles, the value of c in equation (1) must, as far as it pertains to those axial rays, coincide with the value of $\frac{v^*}{v}$ as determined by the Lagrange-Helmholtz formula. But as the condition of aplanatism requires the *same* value of the quotient $\frac{\sin u^*}{\sin u}$ for *all* rays of the wide-angled pencil, we must have for all cases

$$c = \frac{n}{n^*} \cdot \frac{1}{\mathrm{N}}. \qquad (5)$$

Introducing this expression of c into equation (3) and taking into account that in the case of the Microscope the medium at the back of the system is always air ($n^* = 1$), the linear semi-opening of an objective is

$$\rho = \frac{l}{\mathrm{N}} \cdot n \sin u \, ; \text{ or } \rho = \frac{l}{\mathrm{N}} \cdot a, \qquad (6)$$

a being put for n sin u, and therefore denoting *the product of the sine of the semi-angle of aperture and the refractive index of the medium* to which this angle belongs.

When an objective has a focal length $= f$ and an image is projected at a distance $= l$ from the lens, the amplification N of this image will be, very approximately,

$$\mathrm{N} = \frac{l}{f},$$

whence it follows

$$\frac{l}{\mathrm{N}} = f.$$

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† 'Physiologische Optik,' 1866, p. 50.

‡ Mém. Acad. Berlin, 1803.

The quotient appearing in the expression of ρ is thus shown to be nothing else but the equivalent focal length of the system; and we have now

$$\rho = f(n \sin u), \text{ or } \frac{\rho}{f} = n \sin u = a.\dagger \qquad (7)$$

The ratio of the linear semi-opening of any system to the focal length of the system is expressed by the value of a or by the "numerical aperture." The value of n sin u is the aperture-equivalent of every objective whatever may be the medium in which the radiant is placed.

III.—*Inferences from the Aperture-equivalent.*

The simple result of the foregoing demonstration may be summarized as follows:—

(1) There exists a definite ratio between the linear opening and the focal length of a system, which must be entirely independent of the composition and arrangement of the system, and *solely* determined by the above-mentioned aperture-equivalent of the admitted cone of rays. When this equivalent is the same, we have always the same proportion of opening to focal length, whatever may be the particular arrangement of refracting media in the system.

(2) A purely *angular* determination of aperture is shown to be irreconcilable with any rational notion of a term which must be defined essentially in relation to opening. Aperture it is seen cannot be expressed by an angle, nor by any mathematical function of an angle alone, but must be determined by a *composite function* of the angle and the refractive index of the medium to which the angle belongs.

(3) Even with one and the same medium at the radiant, aperture does not increase or decrease in proportion to the angle, but with the *sine* of the semi-angle (or the chord of the whole angle). If the angle is changed from 60° to 180°, the aperture is not changed in the proportion of 1 : 3, but of 1 : 2 only.

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† The above formulæ hold good in *perfect strictness*, if the distance l of the image is taken *not* from the accidental plane of the back-surface, but rather from the posterior *principal focus* of the system (i. e. the place where are depicted distant objects in front of the system). The equation (7) will therefore afford a *strict* expression for the semi-diameter of the emergent pencil *at the plane of the posterior principal focus of the system.* In microscope-objectives of the ordinary type of construction that focus is always very near to the back lens of the system, and the difference may be disregarded practically.

At first sight it might appear to be more convenient to define the aperture-equivalent by $2\,n \sin u = 2\,a$, instead of a, in order to express the ratio of the *diameter* of the opening (instead of the *semi*-diameter) to the focal length. In mathematical dioptrics, however, the angles of the rays *with the axis*, and, correspondingly, the distances of points *from the axis* are always given as the effective elements. To introduce the double of these angles and distances is not only unnecessary, but would give rise to a somewhat inconvenient complication of all mathematical expressions.

(4) Equal angles of the admitted pencils from radiants in different media do not yield equal apertures, but apertures which are in the exact ratio of the refractive indices of those media. Thus the diameter of the emergent pencil of an immersion glass which takes in a cone of say 120° from an object in balsam, is *greater* in the proportion of 3 : 2 than the diameter of the emergent pencil of a dry lens of equal power admitting the same angle from an object in air. Attentive microscopists and opticians have long since noticed the fact, that immersion objectives require and utilize much larger back lenses than equal-power dry systems of similar aperture-*angle.*

(5) An immersion objective may have a greater *aperture* than any dry lens of even 180° aperture-*angle* can have. The maximal opening of a *dry* lens (i. e. the maximal diameter of the pencil emergent from such a lens) is shown by proposition (7) to be exactly double its focal length, for as $\rho = f\,(n \sin u)$ and $n = 1$ and $\sin u = 1$ for air, $\rho = f$ or (for the whole diameter) $2\,\rho = 2f$. No lens performing on objects in air ($n = 1$) can therefore ever admit of a wider aperture, because no angle u is possible whose *sine* is >1. When, however, the object is in a denser medium (and no film of air with plane surfaces is between that medium and the system) an *angle* of aperture which is much less than 180° (exceeding only the double of the critical angle for the medium) will utilize and require a wider opening of the system than $2f$. The excess of the numerical aperture of an immersion glass beyond the unit gives a direct expression of the *surplus* of aperture over the maximal aperture of a dry lens of an air-angle of 180°.

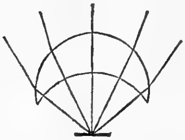
(6) The unit of aperture is exhibited by an objective which gathers-in the whole hemisphere of radiant light *in air.* The value of a for any given objective shows the capacity of that objective in comparison with the capacity of another of maximal air-angle.

Any one who has not comprehended the generality of the demonstration, may object that the greater or less opening required for the transmission of a pencil of given angle depends on the particular mode in which that pencil is refracted by the lens-surfaces of the system. A pencil of 120° in air requires, it will be said, a smaller opening than the same pencil in balsam when a homogeneous-immersion objective is used, because in a dry lens it is contracted on its entrance into the system by the refraction of the plane front-surface, whilst the pencil in balsam, owing to the abolition of the front-refraction by the immersion, is not subjected to such contraction, and *therefore* maintains a greater linear diameter up to the plane of emergence.

The fallacy of such an objection is readily shown: Take a front lens with a *concave* surface of admission, of such a curvature

(Fig. 112), that the focus or radiant for an uncovered object is exactly at its centre. The refraction is now abolished (in regard to the pencil from the radiant) just as if there were homogeneous immersion. If the above-mentioned view were correct, the consequence ought to be, that a dry lens with such a front would utilize a wider opening than an equal-power dry lens of the ordinary plan, and the same opening as an equal-power immersion glass of a balsam-angle equal to the air-angle in question. But, of course, the contrary is the actual fact. An ordinary dioptrical computation shows that whenever such a dry objective with concave front has the same power or focal length as a plane-front system of equal aperture-angle, its opening must be also the same, exactly —as the general principle of formula (7) indicates.

FIG. 112.



A misapprehension on this point has arisen thus:—If a homogeneous-immersion objective is taken, and its front-surface is ground to a concave of the above description, *whilst all other elements are left unaltered*, the angle admitted from air by the objective will be no wider than that which was previously admitted from balsam, but nevertheless the full opening will still be utilized. This seems to prove, and indeed has been asserted *to* prove, that after abolishing the front-refraction, a given air-angle will yield the *same* opening as an equal balsam-angle. This, however, is a transparent fallacy. According to well-known elementary propositions, a concave surface *diminishes* an object at its centre in the proportion of the refractive index n of the lens-substance. Consequently, the objective in question has been changed into an n-times *lower* power; and utilizing still only the *same* (and not a larger) back lens, it has necessarily a *smaller* aperture. To restore the original focal length it would be necessary to increase the depth of the posterior lens-surfaces in such a way that the pencil should be by them contracted to the same small diameter which otherwise it would have had with a plane front.

Whatever particular composition of objective is considered, the result must always be the same. The relation between the aperture-angles for different media and the corresponding openings of the systems, as defined by proposition (7) cannot depend in any way on the manner in which the pencils are refracted in the system. A pencil from a radiant in air must *always* yield a smaller aperture than an *equal* pencil from a radiant in balsam, whether there is refraction or no refraction at the front surface of the system. *Consequently the difference of aperture with equal angular pencils in different media must originate from a difference in the pencils themselves, that is, must be founded on the different physical nature of pencils in different media.*

IV.—*Experimental Demonstration of the Aperture-equivalent.*

In the foregoing discussion I have demonstrated the aperture-equivalent without regard to experiment and on *general* optical principles only, as is necessary for an exhaustive scientific settlement of the subject. A theoretical discussion of this kind is, however, by no means required for demonstrating the *essential* principle of "numerical" aperture. That there is an *unequal equivalent of equal angles in different media* in regard to *aperture*, is a fact which may be readily shown by observations of the most simple character. I confine myself to a few examples which have been referred to in previous discussions.

(1) If any dry lens of an aperture-angle w for objects in air, is focussed on a balsam-mounted object, with a *plane* surface of exit, the aperture-*angle* at the radiant is of course reduced to a smaller angle v, according to the condition

$$n \sin \frac{v}{2} = \sin \frac{w}{2},$$

in which n denotes the refractive index of the balsam. It is, however, clear *that the amplification of the image is not changed* —the power of the system is the same still—whilst the linear diameter of the emergent pencil remains the same also. Consequently, the ratio of the opening to the focal length—i. e. the aperture—is not reduced.

This simple fact thus contains a direct proof of the proposition that *different angles* in different media may denote *equal apertures.*

The idea of aperture being, as has been said, dependent on that of "opening," the assertion that aperture is "cut down" by the balsam, or by the immersion, is obviously an abuse of the term, independently of the fact that the assertion is not supported in any way by what we know as to the actual performance of objectives with these "cut-down" apertures.

(2) Moreover, suppose the same objective of w° air-angle to be focussed on an object in balsam, the surface of exit, however, being no longer a plane surface, but a spherical one, the object being at the exact centre of a small hemisphere of glass or balsam;—or suppose the original objective to be provided with an extra immersion-front, the centre of the curvature of which coincides with the focus. In this case the *angle* of the admitted pencil will be the same for the radiant in glass or balsam as it was for the radiant in air; and the clear opening will also be the same still. It would, however, be obviously a mistake to say that the objective had now undergone *no* change of aperture, or that the *full* aperture was *now* made to bear upon a balsam-mounted object. For it is an

elementary truth that a hemisphere of refractive index n *amplifies* an object at its centre by exactly n diameters. Consequently the hemisphere or extra front has changed the original objective into one of n-times higher power or shorter focal length, *but it nevertheless utilizes the full opening of the lower power.* Consequently the aperture is also increased in the proportion of $1 : n$, whilst the aperture-*angle* remains the same.

If, for instance, a $\frac{1}{4}$ of, say, 60° air-angle has the extra front of crown glass, it would be converted into a $\frac{1}{6}$ of 60° *balsam*-angle, utilizing *the full original opening* of the $\frac{1}{4}$. But a $\frac{1}{6}$ of 60° *air*-angle would of course have a smaller opening than a $\frac{1}{4}$; for such an objective would be obtained by reducing all elements of the former $\frac{1}{4}$ in the proportion of 3 : 2, whereby the opening for the air-angle of 60° would be reduced in the same proportion.

Thus it is shown that *equal angles* pertaining to different media are *different apertures.*

(3) The other inference from the principle of the aperture-equivalent—that an immersion objective can have a *greater* aperture than the widest-angled dry lens—also admits of a direct experimental demonstration. Mr. Stephenson[†] has already pointed out the remarkable experiment (and has given due prominence to its bearing on the aperture problem), by which it is shown to every one's *eyes* that the aperture of a wide-angled immersion glass is *cut down,* when it is made to act as a dry lens even with an angle of nearly 180°. Take any immersion objective of balsam-angle exceeding the double of the critical angle, and focus it on a balsam-mounted object which is illuminated by any kind of immersion condenser, in such a way, that the whole range of the aperture-angle is filled by the incident rays. Remove the eye-piece and place the pupil of the eye at the place where the air image is projected by the objective, and look down on the lens. You see a uniformly bright circle of well-defined diameter which is the true cross-section of the image-forming pencil emerging from the Microscope (for the eye receives now all rays which have been transmitted through a small central portion of the object—that portion which is conjugate to the pupil —and receives *no other* rays). After this, focus the *same* objective on an ordinary dry-mounted preparation (or on one which is connected with the slide, the cover-glass being put on dry), and repeat the observation; you will now see again a well-defined circle, a cross-section of the emergent pencil, but of *less* diameter than in the former case, surrounded by a dark annulus, visible by faint diffused light only.

The diameter of the emergent pencil in both these experiments may be accurately *measured* if the "auxiliary Microscope" of the author's apertometric apparatus is used with an eye-piece micro-

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[†] See this Journal, ii. (1879) p. 267.

meter. The proportion of the clear openings (or effective diameters) with the object in balsam or in air may thus be strictly ascertained. If the objective should be rated at, say, 1·20 num. ap., the ratio of the diameters will always be found 6 : 5 (i. e. as 1·20 to 1·00); and if, in another objective, the num. ap. should be 1·40, this ratio will always be as 1·40 to 1·00 or as 7 : 5.†

The interpretation of this experiment is plain. In focussing an immersion objective on an object with air above, it is obviously converted into a true dry lens, the under surface of the covering glass acting as the plane front-surface of the system. If the covering glass is very close to the object the distance of the radiant from the plane surface will be so small that an exceedingly small central portion of this surface is sufficient for admitting to the front all rays up to an obliquity of 88° to 89°. The objective then acts as a dry lens of nearly 180° aperture-angle, and gathers-in almost the whole hemisphere of light from the radiant in air; whilst the same systems when focussed on an object in balsam, admit no wider cone (in the examples mentioned in the preceding paragraph) than 108° or 138°, in fact much less in each case than a hemisphere. Nevertheless, the emergent pencil of rays is much *narrower* with the whole hemisphere of rays in air than it is with the smaller cone of rays in balsam, *whilst the amplification of the image is not increased*—the power of an optical system of any kind whatever being exactly the same, whether there is refraction or no refraction at its anterior *plane* surface.

Every one will concede that there is a true reduction of *aperture* when a brass stop is inserted at the back of a given system, stopping off a certain marginal zone of the clear opening which

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† According to the general proposition (7) the linear diameter of the *reduced* opening of an immersion glass with a dry object must be $= 2f$, provided the film of air beneath the covering glass be very thin. By measuring the reduced opening of such an objective in the way suggested above, and taking its half, the exact focal length of the system is obtained.

The same principle may be made use of for objectives of every kind. When the numerical aperture of an objective (or the numerical equivalent of any smaller angle within the aperture-cone) is determined, and the linear diameter of the corresponding emergent pencil *at the plane of the posterior principal focus of the system* is measured micrometrically, the focal length is at once obtained from formula (7).

The author has for many years applied this very convenient and accurate method for measuring focal lengths.

On the other hand, the proposition (6) also indicates a new method for measuring apertures and aperture-angles. When the amplification N of an objective for a definite position of the image O^* is ascertained, by projecting the image of a stage-micrometer upon an eye-piece micrometer, the auxiliary Microscope may be focussed to any convenient plane and the linear diameter 2ρ of the emergent pencil measured there. If now the distance l of that *same* plane from the image to which the amplification N relates, is measured likewise, we have all the elements for computing the strict value of $a = n \sin u$—and of the angle u also—by means of formula (6). This method enables us to measure immersion-apertures without requiring a disk of glass or similar devices.

was formerly utilized by the image-forming rays.[†] It must also be a *true* reduction of aperture when, in any way whatever, the emergent pencil is changed *as if* such a brass stop had been inserted, provided the power of the system is unaltered. Consequently we have *loss* of aperture when an air-angle of 180° is substituted for a balsam-angle of, say 100°.

An immersion objective of balsam-angle exceeding twice the critical angle has therefore a *greater aperture* than any dry lens can ever have.

V.—*Different Angular Distribution of the Rays in different Media.*

The definition of aperture as *relative opening*, developed in the foregoing discussion, is, it is seen, the only one which is justified by the original sense of the term, and it is a point of special importance that it should be understood that the definition is not a matter of mere terminology, but that the very *essence* of the idea of aperture is involved in the notion of opening, and that there is no other reasonable base for grasping this essence. In whatever way the idea of aperture may be defined, the actual *significance* of that element in the Microscope can only be appreciated by taking into account the image-forming pencil *emergent* from the objective, and the change in its diameter consequent upon the admission of different cones of light. This diameter affords a visible indication of the *number of rays* (not mere *quantity of light* photometrically) which are collected to a certain area of the image, *and which consequently must have been gathered-in by the lens from the conjugate area of the object.* If, in any case whatever, the diameter of the emergent pencil is seen to be increased, whilst the amplification of the image and the distance of its projection (or, more generally speaking, the focal length) are unchanged, it is clear that the system must have admitted *more rays* from every element of the object, because it has collected more to every element of an *equally enlarged* image. It would be an obvious physical absurdity to declare that in any case a lens could emit more than it has taken in. *Consequently we get a true measure of what is admitted by a system by estimating what it emits.*

Thus the essential idea of aperture (which means the greater or less capacity of objectives for gathering-in rays from the objects) necessarily leads to the estimation of apertures by the *openings* of the systems.

As long as we have the radiant in one and the same medium,

[†] If it should be objected that in wide-angled immersion glasses the marginal zone does not transmit image-forming rays, every one may satisfy himself at once by a simple practical trial that in a well-corrected objective all emergent rays up to the edge of the clear opening *are* image-forming rays.

the increase of the *admitted* rays with increased *opening* is very simply accounted for. We *see* the additional portions of the solid cone from the radiant, which correspond to the additional portions of the enlarged opening. But if in any other case (for instance, when the medium is different) we see that a certain solid cone A from a radiant is transmitted through a certain opening a, and that another solid cone of rays B cannot be transmitted through the same opening a, but requires a wider one β, *whilst all other circumstances, except those of the radiant, have remained the same,* we can of course only conclude that the pencil B must contain rays which are not contained in A, even if the admitted cone is not increased in size. For the additional portion $(\beta - a)$ of the wider opening β conveys rays to the image which are certainly not conveyed by the smaller opening a. Whence can this surplus come if *not* from the radiant? Obviously the pencil B, which requires the additional opening, must embrace *more* rays, even if it should not be of greater *angle.*

Now the fact is, that a given objective may collect the rays from a radiant *in air* almost to the entire hemisphere (as, for instance, in the case of an immersion lens when focussed on a dry-mounted object close to the covering glass) and it then utilizes a definite opening, double its focal length. But when the radiant is in balsam (without any other alteration), the same opening is seen to be utilized by the rays which are within a smaller cone of not more than 82°, and rays which are outside this cone require a surplus of opening, which is never required for rays in air. This holds good, as has been shown, whether there be refraction or no refraction at the front surface of the system; the difference is based *solely* on the difference of the medium. Consequently we arrive at the conclusion that the solid cone of 82° in balsam embraces the same rays which in air are embraced by the whole hemisphere; and every wider cone in balsam, exceeding the 82°, conveys *more* rays from the object than are admitted by the whole hemisphere of radiation in air.

The definitive inference from the foregoing consideration is obvious. There is no way of reconciling the seeming contradiction between these two facts, (*a*) that a cone of $> 82°$ from a radiant in balsam embraces *more rays* than a cone of 180° from a radiant in air, and (*b*) that the *angular* extension of the former cone is less than that of the latter, except by admitting the physical fact that the *same* rays which in air are spread over the whole hemisphere, are closed together, or compressed, in balsam within a narrower conical space of 41° around the perpendicular; and all rays which travel in balsam outside this cone constitute *a surplus of new rays, which are never met with in air, that is, are not emitted when the object is in air.*

There are various direct proofs that the *angular* distribution of the radiating light is changed whenever the medium of the radiant is changed. The rays which emanate from a given object in different media are not, it is true, numbered like the sheep of a flock, and it is impossible therefore to show the identity or non-identity of certain rays under different circumstances without having first established an express *principle of identification.* This will be required for the view above expressed just as well as it would be required if any one should try to prove the (assumed) indifference of the medium in regard to radiation. There is one particular case, which however is of considerable importance for the Microscope, in regard to which such a principle may be readily established.

When a preparation contains transparent (perfectly pellucid) portions, the depiction of which yields the outlines of the non-transparent elements in the microscopic field, the rays emitted from such portions are purely *transmitted* rays. Every ray emanating from a transparent element of the object is the direct continuation of *one* distinct ray which is thrown upon that element by the illuminating apparatus. Suppose now an object of this kind, having a perfectly flat upper surface, and connected to the slide, in the one case uncovered, in the other case mounted in water or balsam under a cover-glass, and illuminated by means of an immersion condenser which collects a pencil of not less than 82° (measured within the slide) upon every point of the microscope-field. In both these cases one and the same transparent element will send into the objective, by virtue of transmission, the *same* incident rays; but when the object is in air, these same rays are distributed above the object in a different manner to that which obtains when the object is in water or balsam. In the former case all rays which are embraced by an incident cone of 82° within the glass slide make up the whole hemisphere; whilst with water above, the *same* rays are contained within an emergent cone of 96°, and with balsam within 82°.

Under the circumstances in question, those rays transmitted through the object are of course *identical* rays—notwithstanding their different directions in air, water, or balsam—which are the continuation of identical incident rays. In regard to that kind of radiation, therefore, on which the delineation of the *outlines* of non-transparent or semi-transparent objects is based, a pencil of 82° in balsam or of 96° in water, conveys the same rays to the Microscope as the whole hemisphere in air, and there is a different angular distribution of the radiating light in different media. In this case the *causa efficiens* of the phenomenon is, of course, the different refraction with which the transmission is connected. A dioptrical explanation of the varying distribution does not, however, change the fact that there *is* such distribution.

A *general* criterion of identical and non-identical rays in different media, which applies to every kind of radiation and leads to the same conclusion, is obtained when we refer to the *physical* notion of a ray. Physical optics defines "rays of light" as the orthogonal trajectories through a system of waves. The principle of this definition implies, at the same time, that "homologous rays" in different wave-systems are to be determined with regard to the rate of propagation in these systems; and it is found that homologous rays are *closer* together when the velocity of propagation is *less*, and *vice versâ*—in perfect analogy to the "lines of force" in a magnetic or electric field when the electric or magnetic charge is increased. The direct outcome from this is, that identical rays emanate under smaller angles of obliquity in a medium of higher refraction, and, in general, one and the same system of rays constitutes cones of different angles in air, water, or balsam, in such a way, that the "numerical" equivalents of these various cones (the product of the *sine* of the semi-angle by the refractive index) are always the *same*.

This theoretical inference bears directly on that kind of radiation which is the most important one for the Microscope—the radiation of objects by *diffracted* light. Every structural object, whether the structure is regular or in any way irregular, which transmits or reflects a narrow-angled incident beam of light (or any number of such making together a wide-angled cone) changes this beam (or each one of the several beams) into a wider or narrower *pencil*, with varying intensity in different directions, by virtue of diffraction. The interference of elementary waves emitted from the transparent or semi-transparent elements of the structure neutralizes the undulatory motion above the object in some directions, whilst in other directions the survival of the motion, or of a fraction of it, develops rays of light of various intensities, which emanate from the object in various directions as if it were self-luminous. In the case of regular *periodic* structures, as lined objects, diatoms, &c., the diffraction pencil originating from an incident beam appears as a fan of isolated rays of decreasing intensity around the direction of the incident beam transmitted through the structure—the interference of the primary waves yielding in this case a number of successive maxima of light with dark interspaces. According to the well-established laws of the diffraction phenomenon, the fan of diffracted beams from one and the same structure is spread out under a wider angle when the wave-length of the medium is increased or the refractive index is diminished, and is more compressed together in the opposite case; in such a way, that the *sine* of the angle of obliquity of the *same* beams—for instance, the first, or second . . . maximum—is changed in the inverse ratio of the index. Owing to this, one and the same solid cone at the object will embrace a larger number of diffraction beams in balsam than in air; and if the elements of the structure are very minute a solid cone exceeding in balsam the angle of 82° will contain beams which do not exist at all when the same structure is in air, because they cannot be originated except with waves of *shorter* length than are in air.

Experiments, which have been fully described, demonstrate *ad oculos* the admission of these beams of diffracted light to the Microscope and the *effects* which are attendant upon the admission of more or less of them in regard to the microscopical image. It is shown that the diffracted light emanating from the objects may utilize the *whole* aperture of a system, although the incident cone of light, if it were simply transmitted (in the absence of an object), would fill only a small portion of the aperture. In particular it may be seen experimentally, that with a narrow illuminating pencil a wide-angled immersion glass may gather in, and collect to the image, rays from an object in water or balsam, which are not met with in the whole hemisphere when the object is in air, and consequently can never be utilized by a dry lens of any aperture-angle whatever.

Owing to the general principle of physical optics mentioned above, homologous diffraction beams from one and the same structure—for instance, the first, or second . . . maximum in the case of a periodic structure—are the *same* rays *physically*, notwithstanding their different obliquity, and diffraction beams which show the same obliquity in different media are *different* rays *physically*. Thus the phenomena of diffraction in the Microscope afford another experimental proof of the validity of the inference from the principle of the aperture-equivalent: *that there is an unequal angular distribution of radiation in different media, and that a given solid cone from a radiant in balsam may contain more rays than the same cone from a radiant in air, because the same rays are closer together, and others are introduced.*

The above considerations lead to the following conclusions:—

(1) The unequal equivalent of equal aperture-*angles* indicates a different *number of rays*, as conveyed by *equal* cones in different media consequent upon a different *density* of radiation in such media; and this is quite distinct from any photometrical estimation of the *quantity of light* in these cones, which may vary independently according to the illumination of the object, the change of its surface by different media, &c.

(2) An aperture-cone exceeding twice the critical angle of the medium to which it pertains, embraces a surplus of rays which do not exist, physically, when the object is in air, because they are *not emitted into air*. A wide-angled immersion glass, therefore, may utilize rays from an object in

> a denser medium, which are entirely *lost* for the image—which, in fact, do not exist—when the same object is in air or is observed through a film of air. *This loss can never be compensated for by increase of illumination,* because the rays which are lost are *different* rays, physically, to those obtained by any illumination however intense in a medium like air.

It is not surprising that a notion of aperture—the *angular* notion—which is so incomplete and so misleading in regard to the most characteristic feature of the performance of the Microscope should have been abandoned. Adhering to the angles merely, and disregarding the influence of the medium, has entirely concealed from many microscopists even those plain truths which have long ago been settled by the *practical* use of the instrument. Inasmuch as the experience of two decades has established beyond any doubt the fact, that immersion objectives readily depict minute structures which are not shown by the most perfect dry lens, *whatever may be the illumination,* it is strange that it can still be supposed anywhere at this day that the true advantage of the immersion method cannot be anything beyond greater convenience in regard to working distance and some (very moderate) gain of light from the abolition of front-reflection—*because* the aperture-angle of these objectives cannot be greater than with dry lenses.

If any person, who agrees that a rational definition of aperture can only be established on the basis developed here, should yet dislike the expression "*numerical* aperture"—for any reason whatever—I certainly do not object to another term, if a *better* can be found. In point of fact, I was obliged to introduce this term for the mere sake of preventing confusion. It is in reality objectionable, as the word "numerical" conveys the idea that a *particular* description of aperture, among others on an equal footing, is intended to be denoted. From my point of view, the aperture-equivalent should be called "aperture" *sans phrase,* because it *is* "aperture *sans phrase.*"

VI.—*The Photometrical Equivalent of different Apertures.*

Difference of aperture must of course always correspond to a different *quantity of light* admitted to the objective, provided all other circumstances are equal; and thus the question of aperture has necessarily also a photometrical aspect which leads to the consideration of the *photometrical* equivalent of different apertures or aperture-angles. But it is clear that this point of view does not meet the real essence of the aperture problem. The brightness of the image (which of course *alone* will depend on the photometrical equivalent) is certainly a matter of practical importance in the Microscope; but if a greater aperture signified nothing more than greater quantity of light—if there were no *specific* difference of the rays which can be utilized by different apertures—the whole question would be only of somewhat subordinate interest. More light *from* an object can always be gained when more is thrown *upon* the object by means of a brighter source of illumination.

Inasmuch, however, as the determination of the photometrical equivalents of different apertures affords an additional *illustration* of numerical aperture, it will be useful—for the sake of completeness merely—to add a brief outline of the photometrical principles relating to the matter, though nothing can be said here which has not been established long ago.

(1) In the last century Bouguer† and Lambert‡ established the important fact that with any surface of *uniform radiation* (so called) the intensity of the emitted *rays* is *not* the same in all directions. The *power of emission* and the intensity of the rays (i. e. the quantity of light emanating from a given surface-element within a cone of a given *narrow* angle) varies in the proportion of the *cosine* of the angle of obliquity under which the ray is emitted. This proposition is nothing more than the expression of the simple fact, that a surface of uniform radiation shows the same visual brightness in all directions; and that such a surface, if curved (for instance the sun, or the porcelain shade of a lamp, &c.), is always seen projected as a surface of *uniform brightness.*

This theorem, which at a later period was confirmed by Fourier, Melloni, and other physicists, shows at once that the quantities of light emitted from one and the same object within solid cones of different angles are *not* in the ratio of these solid cones, but in the ratio of the squares of the *sines of their semi-angles.* Thus the whole emitted light (embraced by the entire hemisphere of radiation), and that portion which is emitted within a cone of 30° around the perpendicular (or 60° angle) are not, as is so constantly assumed, in the ratio of 7·46 : 1 (as the solid cones in fact are), but in that of 4 : 1 only.

As in one and the same medium the number of rays conveyed by a pencil and the photometrical quantity of light are proportional, this old-established Lambert theorem is sufficient of itself for overthrowing the very basis of the *angular* expression of aperture, and for proving that even when we are dealing with one and the *same medium* only, the *angle* is not the sufficient expression, but that it is the *sine of the semi-angle* which must be taken.

(2) In more modern times, but still seventeen years ago, a distinguished physicist, well known in England, R. Clausius, established by a famous research "On the Concentration of

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† 'Traité d'Optique sur la Gradation de la Lumière,' 1760.

‡ 'Photometria,' 1760.

Calorific and Luminous Rays and the Limits of its Efficiency,"† another proposition pertaining to radiation in *different media*, viz. that the *power of emission* of a body—in regard to heat as well as to light—is not the same in different media, but varies in the ratio of the squares of the refractive indices, so that the *whole* emitted light from any surface-element of a self-luminous body is increased in the proportion of $1 : n^2$ when this body is brought from air into a denser medium of refractive index n. If a glowing body at a constant temperature, such as a bar of iron, could be immersed in a medium of 1·5 refractive index, in such a way that the surface were in optical contact with the medium, and the eye of an observer immersed likewise (the diameter of the pupil being kept unaltered and the loss of refraction at the cornea compensated for), the body would be seen *brighter in all directions* in the proportion of 9 : 4 than it appeared in air.

The principle of Clausius applies also to the diffused radiation of non-self-luminous bodies, provided their internal structure and surface are not changed by the surrounding media. An object which fulfils this condition (without which of course there could not be a constant illumination)—for instance, a polished plate of porcelain glass—gives out by diffused reflection or by diffused transmission a *greater portion* of the incident light, if the radiation takes place into oil or in any other dense medium, than when it takes place into air as can be shown by a simple experiment.‡

The principle of this varying emission in different media is not so far from a rational explanation as it may appear on a superficial consideration. "Quantity of light" is the energy of an undulatory motion. A "constant illumination," or equal intensity of radiation, means equal *amplitude* and equal *frequency* of the undulation at the radiating surface. These circumstances being equal, the amount of undulatory energy which is transmitted by the waves to any definite surface (for instance, to the whole surrounding hemisphere) must depend on the *density* of the propagating medium which is excited by the primary motion—because the *vis viva* of *every single wave* of given amplitude is greater in the proportion of this density. In fact, the stroke of a bell or the human voice is found to give a louder sound in the dense atmosphere at the level of the sea than in the rare air on high mountains. According to the theory of Fresnel, the relation of the densities of any two media in respect to the propagation of luminous

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† "Ueber die Concentration von Wärme- und Lichtstrahlen," &c., Pogg. Annalen d. Physik, cxxi. 1864.

‡ The author has furnished to Mr. Crisp a little piece of apparatus for demonstrating *ad oculos* the fact, that a thin polished plate of porcelain glass illuminated from the back, throws, from a given area, an evidently greater quantity of light into a block of crown glass (cemented on), than an equal area of the same plate under exactly the same illumination throws into air.

waves is expressed by the *squares of the refractive indices* of these media.[†]

(3) Further, in 1874 another well-known and distinguished physicist, Helmholtz, confirming certain propositions of the author which were directed to the same subject, demonstrated[‡] a similar principle pertaining to the photometrical equivalent of the pencils of light which travel from a luminous object through different media *successively*. In this case the quantity of light conveyed by *equal* solid cones is also in the ratio of the squares of the refractive indices of the media.

From these established theories of photometrical optics it is seen that the *quantity of light* emitted from an object under a given illumination is *not* measured by the angle of the emitted cone at the radiant, nor can it be measured in any way by means of the angle *alone*. The quantity depends under all circumstances on *the product of the sine of the semi-angle and the refractive index of the medium in which the object emits*, and is expressed by the square of this product, or by the square of the "numerical" aperture of the pencil.

Thus it is shown that the *general* aperture-equivalent, which is defined by the value of a, indicates at the same time the *photometrical* equivalent of different apertures.

The practical outcome, as regards microscopical vision, of this photometrical inference is the general proposition of the *illuminating power* of the Microscope, or the brightness of the microscopical image, first propounded in the author's paper of 1873,[§] and in that of Professor Helmholtz quoted above:—

If the losses of light by reflection and absorption in an optical system are disregarded, the brightness of the microscopical image under a given illumination of the object depends *solely on the linear diameter of the transmitted pencils of light at their emergence from the ocular*, and is always the same when this diameter is the same, whatever may be the composition of the Microscope (objective, eye-piece, &c.) and the amplification of the image. The diameter of the ultimate emergent pencil, or the cross-section of this pencil, is *visible* within the so-called "Ramsden circle" above the

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[†] The supposition of *cold* and *hot* air would render the accordance of the circumstances of the acoustical and the optical phenomena still more complete. But as, under the point of view in consideration, the *causa efficiens* is the density of the medium, and not the velocity of propagation, the difference is immaterial.

The above popular elucidation of the principle is not, of course, intended as a scientific demonstration. It is only given for the purpose of showing that common sense is by no means on the side of opposite opinions. The demonstration of Clausius, moreover, does not depend on the hypothesis of Fresnel nor on any other assumption which can be a matter of dispute among physicists.

[‡] "Die theoretische Grenze für die Leistungsfähigkeit der Mikroskope," Pogg. Annalen d. Physik, Jubelband 1874, p. 564.

[§] Arch. f. Mikr. Anat., ix. (1873) p. 438.

ocular. When this diameter is greater than, or at least equal to, the diameter of the eye's pupil, the brightness of the image has its *maximal* value, which can never be increased, and is the same brightness which would be obtained with direct vision by the naked eye, of any large object under the same illumination; and when the ultimate diameter of the emergent pencil is the kth part of the pupil's diameter, the brightness of the image is the k^2th part of the brightness of unaided vision.

Denoting by Δ the conventional distance of distinct vision, by N the linear amplification of the image projected to this distance, $\frac{\Delta}{N} = \phi$ will be the equivalent focal length of the total Microscope. If then a is the numerical aperture of the admitted pencil (which may utilize either the whole aperture or a part of it only), the diameter δ of the ultimate emergent pencil at the plane of the Ramsden circle will be according to proposition (7) of Sec. I.

$$\delta = 2\, a\, \phi,$$

which is the diameter to be compared with that of the pupil in order to obtain (by the squares) the ratio of the brightness of the microscopical image to the brightness in vision with the naked eye.

The different *photometrical* equivalent of equal angles in different media, may be plainly demonstrated by several observations which are already well known, and within the reach of every microscopist, but I may briefly indicate some of them here.

(1) Objects are seen with *equal* brightness, with the naked eye and with the Microscope, whether they are uncovered or protected by a covering glass cemented on, provided their pellucidity is not changed by the surrounding medium. (No such change takes place, for instance, with perfectly transparent portions or elements of a preparation.) It is evident that the pupil of the eye, or the objective of the Microscope, admits from every radiant in air a *wider angular* pencil than from the radiant in balsam, as the latter pencil acquires the angular width of the former by an *expansive* refraction at the surface of exit. The diameter of the object under the covering glass is not of course reduced by this refraction, but appears of the same size still, and consequently the narrower pencils emanating from the object in balsam must convey the *same quantity* of light as the broader pencils emanating in air.

(2) When a hemisphere of glass is cemented to a preparation and the condition above referred to is fulfilled, the object appears just as bright as it appeared uncovered, as well with the Microscope as with the naked eye. In this case the divergence of the pencils at their exit into air is not changed, and the pupil of the eye or the lens-opening receives equal pencils under both circumstances. But as the hemisphere amplifies the object at its centre in the

proportion of 3 : 2 linear, and the surface in the proportion of 9 : 4, it consequently *gives out* from every square millimetre of the object as much light as is given out in air from 2¼ square millimetres. Consequently the quantities of light conveyed by equal solid cones in balsam and in air are in the proportion of 9 : 4.

If equal angles at the radiants in both media indicated equal quantities of light, the object *under the glass* ought to appear less bright (in the proportion of 4 : 9) in *both* these experiments.

(3) A third fact exhibits the exact converse of the preceding. Suppose a surface, for instance a sheet of white paper, illuminated by a source of light at a given distance. It will show a certain illumination. Putting on now a hemisphere of glass, that part of the paper which is near the centre of the hemisphere will show an evidently brighter illumination. The visual angle of the source of light from that place is certainly not changed; the solid cones which converge to every one point of the paper are exactly the same still. If, nevertheless, more light is collected to every square millimetre under the hemisphere, the solid cones in glass must convey more than equal cones in air.

The *concentration* of the incident rays at the centre of a hemisphere, is, of course, fully accounted for on the ordinary dioptrical principles—just as the amplification of an object at the centre is. There is nothing mysterious in these observations, but the dioptrical explanation does not alter the *fact*, that there *is* an unequal quantity of light corresponding to equal cones in different media.

VII.—*Relation of the Aperture-equivalent to the general "Delineating Power" of the Microscope.*

The notions of "more" and "less" in regard to the number of rays admitted to different systems, and the conclusions based thereon, are, it will be seen, quite independent of (and much more general than) mere photometrical estimations of quantities of *light*, which of course would relate only to a difference of *brightness* in microscopical images. Nor are these conclusions in any way dependent upon the author's theory of microscopical vision, though the phenomena of diffraction have been adduced above as *one* illustration and experimental support of the general principle. This principle has no *essential* connection either with any particular physical process from which the radiation of microscopical objects may result, or with the laws on which the delineation of the microscopical image may depend. The question so far has not been, whence *come* and how do those surplus rays act, which are utilized by means of a given balsam-angle, in comparison with an equal air-angle, but whether there *is* such a surplus. When *this* is once settled, the preponderance of the former angle over the latter is settled also. For it will be conceded that an objective of 120° air-angle shows more than an objective of 60°, and that it does so *because* it admits *more rays* than the latter. Nobody can deny, then, that a system of 60° balsam-angle must have the same preponderance over the system of 60° air-angle, because *it also* admits more rays—quite apart from the question, *why* does a lens show more if it admits more rays?

At the same time, however, it will not be without interest to refer here to the considerations which show how the subject of aperture in the Microscope becomes one of *general* practical importance.

It is evident that the increase of the aperture-equivalent would not be the basis of progress in the performance of the instrument, if there did not exist a *general* cause by virtue of which such wide apertures are *utilized*. Now, it is quite certain that the illumination of the objects by wider incident pencils of light, does *not* afford such a general utilization. In the practical use of wide-angled objectives, we are for the most part confined to an illumination by rather narrow pencils, which occupy only a *small* portion of the aperture-cone. If we throw upon a delicate object a cone of light sufficient to fill the whole aperture of such a system (which of course *can* always be done by means of a suitable illuminating apparatus) we should in most cases see nothing, or next to nothing. Wide-angled glasses, as is well known, show more than narrow-angled, *although* the direct transmitted rays from the illuminating pencil utilize a small portion only of the clear opening; and in many cases show the more, the more the incident pencil is reduced. Consequently, another reason is required in order to account for the fact, that there *is* a general benefit with the wider aperture.

With regard to rather *coarse* objects, which are perfectly delineated by low-power and narrow-angled lenses, we find several effects which produce an angular expansion or dissipation of the incident pencil above the object—particularly deflections of the transmitted rays by prismatic or lenticular action of the elements. *These effects, however, do not continue* when we have objects with *minute* detail of any kind. Theory and observation unite in the conclusion, that spherical, cylindrical, or prismatic elements not exceeding a few wave-lengths in diameter cannot yield and do not yield anything like lenticular or prismatic deflections.† Whenever

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† By way of example I may refer to the phenomena of the valve of *Pleurosigma angulatum* first pointed out eight years ago. The more general opinion among microscopists is that it is composed of spherules. Inspect now *through* such a valve a bright well-defined luminous object and observe the optical effects of the spherules on the transmitted rays. Notwithstanding the minuteness of the diatom, this may be readily done. With an $\frac{1}{8}$ objective, focus a good specimen at the centre of the field, and after having withdrawn the ocular, bring the pupil of the eye on the air-image of the valve as projected by the system. You will then see the illuminating flame or the clear diaphragm-hole of the condenser *through* the valve, because no ray can reach the eye, which has not passed through that

the details of a structure are so minute, that wide-angled (or even moderate angled) systems are *required* for its delineation, there remains only *one* reason which accounts for a radiation of the object in other directions than those embraced within the incident pencil, and that is the *diffraction* of the light by the structure. By virtue of the diffraction effect attendant upon the transmission or reflection of light by any structure (whatever may be its composition) the incident beams are scattered over a larger or smaller part of the hemisphere above the object; and *thus* a radiation is obtained which, in the case of very minute elements, may fill the whole hemisphere (even in a dense medium), and utilize any wide aperture. Owing to the diffraction effect, microscopical objects radiate, in a certain sense, in the manner of self-luminous bodies, and this the more so as their elements become smaller and smaller. What is generally (and erroneously) called "diffused" radiation of microscopic objects is—with the exception probably of a few particular cases which have no practical importance for the Microscope—nothing else but radiation by means of diffraction beams expanding the incident pencils above the object.

From this point of view a proper estimation of the *actual* importance of aperture in the Microscope, and of the *practical* value of a correct definition of apertures, is entirely based upon the consideration of the phenomena of diffraction in the Microscope. All aperture-equivalents or aperture-angles beyond a very moderate extent would be meaningless and dead things, if there did not exist a general physical process by virtue of which the objects *emit* those rays which *can* be admitted by wide apertures. At the same time it is evident that the original idea of aperture as the capacity of an objective of gathering-in rays from the objects, means but *one* function practically, that of gathering-in a greater or less portion of the *diffracted rays* scattered by the objects. There cannot be any other general benefit of large apertures, because there is no other general cause of a dissipation of light by the objects without which the utilization of wide-aperture cones would not be possible. Diffraction, however, is universal whenever the strictly uniform propagation of luminous waves (transmitted or reflected) is disturbed by the interposition either of opaque or semi-opaque

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portion of the valve which is optically conjugate to the area of the pupil. Provided the mid-rib is not just projected on the eye, the flame or the diaphragm-hole is seen as well defined as if through a plate of glass; you do not see the least deflected or scattered light *except* the bright diffraction spectra arranged around the direct image.

Whilst it is not *my* opinion that the *angulatum*-valve is composed of spherules, yet even if such should exist, they would not have a different effect. We may infer from observation and from theory, that very *minute* spherules, or cylindrical threads, have entirely lost the characters of *refracting* bodies, which are so distinctly exhibited by air-bubbles, fat-drops, &c., of *larger* size. The residual effect of such objects is solely retardation or acceleration of the transmitted waves, by virtue of the *difference* of their own refractive index and that of the surrounding medium; and this is *one* among the conditions of *diffraction*.

elements, or of transparent elements of unequal refraction, which originate unequal retardations of the waves.

Bearing in mind what has been said above (Sec. V.) in regard to the different angular expansion of *homologous* diffraction fans in different media, and remembering that this holds good for *every* kind of diffracting structures, whether of regular or irregular composition, it will be easily seen that whilst numerical aperture indicates the relation of opening and focal length, it also indicates at the same time the true equivalent of different apertures in regard to the smaller or greater portion of the diffracted light, from any given structure, which an objective *can* admit and collect to the image.

The practical importance of the admission of more or less diffraction beams in regard to the image which is depicted by an objective has been shown already by many experiments with various microscopical preparations. Experiments of this kind must, of course, be confined to those structures which permit the direct observation of the diffraction beams and of the influence exercised by their admission or exclusion. This is the case only with regular periodic structures composed of a multitude of similar elements, because these alone yield *bright* and *distinct* diffraction spectra, composed of isolated well-defined portions of light with characteristic colours. Irregular structures, or objects composed of a few elements only, produce diffraction effect also, with no less angular expansion of the rays, but these do not yield distinct spectra nor sufficiently bright beams for convenient observation. The experimental investigation of the subject must therefore be confined to that *particular* action of the aperture-function in the Microscope, which is exhibited in the delineation of lines, striations, field-markings, and similar regular structures, and is known as the "resolving power" of objectives. The study of this particular exhibition of the diffraction phenomena, and of their influence on the microscopic image, affords, however, at the same time an exemplification of the aperture function in its *general* features. It is shown in this way that the admission or exclusion of different portions of the diffraction pencil emanating from an object *can* have a real influence on the image which is delineated, because it *has* such influence, as a matter of fact, with certain kinds of objects.

As, therefore, the *practical* value of increase of aperture is the increased admission of diffracted light from the objects, it is a matter of special importance, for the due appreciation of aperture from this practical point of view, to have a clear answer to the question, *What* is the benefit of this increased admission in the *general* performance of the Microscope, apart from the delineation of lines and field-markings in diatoms and similar objects, which may be said to be of interest only to a few? The definitive outcome of the author's investigation into this subject is fully developed in another paper.† In order, however, to give here a summarized idea of the benefit attendant upon increased aperture, and to indicate *what* it means for the general interest of microscopical vision: difference of the diffracted light which is utilized for the image—I briefly point out here some propositions which are established by theory and experiment in that paper :—

> (1) *Perfect similarity* between the microscopical image and the object, or a true enlarged projection of the object by the Microscope, *always* depends on the admission to and utilization by the objective, of the *whole* of the diffracted rays which the structure is competent to emit.
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> (2) Whenever a portion of the total diffraction fan appertaining to a given structure is *lost*, the image will be more or less *incomplete and dissimilar* from the object; and in general, the dissimilarity will be the greater the smaller the fraction of light admitted. In the case of periodic structures, the exclusion of all diffracted rays, except the central (direct) beam of the diffraction fan, will entirely obliterate the details of the image. With structures of every kind (periodic and irregular) the image will lose more and more the indications of the minuter details, as the peripheral (more deflected) rays of the diffraction spectrum or diffraction pencil are more and more excluded.

For example: When a striation, a grating, or a diatom is close to the limit of the delineating power of a given aperture (i. e. when the distance of the lines is not much greater than $\left.\frac{\lambda}{2a}\right)$ the image is always depicted by *two* diffraction beams only (if with bright field, by the direct, undeflected ray, and *one* spectral ray). In this case the striation always appears as if the darker and brighter interspaces composing the striation were very approximately of *equal* breadth, although the inspection of a *more complete* image of the same structure, obtained by means of a much greater aperture, should show the proportions of the alternate striæ to be *very* different.

Another example: The diffraction fan of isolated corpuscules or threads (say bacteria or cilia), in a clear field, must be exactly identical to that of equal-sized holes or slits of equal shape in a dark background, and there must be (as theory shows) a continuous and nearly uniform dissipation of diffracted light over the whole hemisphere, provided the diameter of the object is very small (a fraction of λ); and this would be so even in a medium of highest known refractive index. Such objects *can* be seen, however minute they may be;

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† 'Die Grenzen der geometrischen Optik in der Theorie des Sehens und der optischen Instrumente.' (The limits of Geometrical Optics in the Theory of Vision and Optical Instruments.) 8vo. Jena, 1881. (In the press.)

this is merely a question of contrast in the distribution of light, of good definition in the objective, and of sensibility of the retina.† But whenever they *are* seen, they are seen *increased* in size, owing to the loss of diffracted light in every medium whose refractive index is not a considerable multiple of the unit. Similar objects of larger diameter—say 10 λ—are delineated of their *exact* size, by objectives of perfect definition, because the diffracted light in this case is not, even in a medium like air, subtended far from the direct beam in perceptible intensity, and the *whole* can be admitted therefore with a moderate aperture.

> (3) When a portion only of the whole diffracted light from a structure is utilized, the image is a true enlarged projection of a *different* structure, namely of one the *whole of whose diffracted beams* would (if it physically existed) be represented by the *utilized* diffraction beams of the structure in question.

For example: If *angulatum*, either in balsam or adhering to the covering glass, is illuminated by a direct incident pencil, it is delineated with a *wide*-angled immersion glass by means of the direct undeflected beam and six surrounding spectral beams. The image which is then seen is not a true copy of the real (quite occult) structure of the valve; but it is a true enlarged projection of *that* structure which (if it could be produced artificially) would break up by its diffractive power an incident beam into a fan (or more strictly "group") composed of the direct ray and the said six deflected rays, *and these alone.* If we illuminate the valve by an oblique incident beam, some of the six spectra are shut-off by the margin of the aperture, and one or two new ones of greater deflection (which remained outside the aperture in the former case) are taken in if the aperture is sufficiently wide. The *effective* portion of the diffraction group is now very unsymmetrical. The image which is *now* seen is the true projection of that *other* structure which would yield this unsymmetrical group as the *whole* of its diffraction effect, such group being identical both in the number and brightness of its beams to the admitted beams.

The great variety of aspects which are obtained from one and the same object merely by change of illumination, is fully accounted for and defined by the above proposition.

Or as another example: A very thin thread—say a minute cilium—only a fraction of λ in diameter, is depicted with considerably increased diameter, even with a very wide aperture. The image is the *true* copy of *another* thread (the composition of which can be computed by theory) which would yield a diffraction fan exactly similar to that which is actually admitted by the objective, but

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† In point of fact, neither Professor Helmholtz nor the author have ever spoken (as, however, has so often been supposed) of a limit of "visibility"—only of a limit of visible "separation."

abruptly broken off at the limit of the aperture-cone (the intensity of the deflected light suddenly cut down to zero at a definite obliquity). Theory shows, that a thread-shaped object which could yield such a particular diffraction effect, must (other differences not considered) be at all events *greater* in breadth than another one yielding the full continuous dissipation of light.†

(4) As long as all distinct elements of a structure are measured by large multiples of the wave-length of light, all diffracted rays of perceptible intensity will travel within a narrow cone around the direction of the incident beam from which they originate. In such a case any narrow aperture-angle will be sufficient to admit the *whole*. The images of such *coarse* objects (or of their coarser parts) will therefore be always perfectly similar to the object, i. e. will be *true* enlarged projections.

(5) When the diameters of the elements of a structure (or of some of the elements in it) are reduced to smaller and smaller multiples of the wave-length which corresponds to the medium in which the object is, the diffraction pencil originating from an incident beam has a wider and wider angular expansion (or in other words the diffracted rays are further apart); and when this diameter is reduced to a few wave-lengths, not even the hemisphere can embrace the *whole* diffraction effect which appertains to the structure. In this case the *whole* can only be obtained by shortening the wave-length, i. e. by increasing the refractive index of the surrounding medium in such a degree that the linear dimensions of the elements of the object become a large multiple of the *reduced* wave-length. With very minute structures, the diffraction fan which can be admitted in air, and even in water or balsam, is only a greater or less *central portion* of the whole possible diffraction fan corresponding to those structures and which could be obtained if they were in a medium of much shorter wave-length. Under these circumstances no Microscope, however wide may be its balsam-angle, can yield *a complete or strictly similar image.*

These propositions relate to structures of all kinds, whatever may be their physical and geometrical composition—isolated elements of any shape not excluded; they embrace the totality of the objects of microscopical research.

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† The theory of diffraction if developed on a more general basis shows that a structure may always exist which is competent to originate as the *whole* of its diffraction effect any given, even discontinuous or abruptly broken off, diffraction spectra, for instance that portion of the actual diffraction spectra of another structure which remains after excluding a certain other portion. Such discontinuous spectra are not obtained with structures (as an ordinary grating) whose diffraction effect is solely based upon *interception* of the rays by varying absorption. They are, however, obtained with structures which occasion at the same time varying *retardation* of the transmitted waves owing to unequal thickness or unequal refractive index of the transparent elements.

They establish therefore a most general signification of the aperture-equivalent. The value of a ($= n \sin u$) indicates the number of rays which an objective *can* admit. The rays which *are* admitted (in such a way that the aperture-cone is truly utilized) are greater or smaller portions of the diffraction pencils originating from the objects. *The greater or smaller the admitted or utilized portion of these rays, the greater or less similarity between the image and the object.* The aperture-equivalent measures, consequently, the very essence of microscopical performance. It *measures* the degree in which a given objective is competent to exhibit a true, complete delineation of structures of *given* minuteness, and conversely the proportion of a in different objectives is the exact measure of the different *degree of minuteness* of structural details which they can reach, either with perfect similarity of the image, or with any *equal* degree of incompleteness of the image—provided, of course, the purely dioptrical conditions of the delineation (defining-qualities, amplification, &c.) are the same.

Numerical aperture is thus the true and general expression of the "delineating power" of the Microscope.†

VIII.—*The Indifference of the Angles quâ Angles in Microscopical Performance.*

The foregoing considerations establish that from all the points of view which have been investigated, the *angle* is not the true basis of comparison for objectives. It is not so either in regard to aperture in general, as far as this idea has any relation to opening; nor is it so in regard to the number of rays (geometrically) or of the quantity of light (photometrically) which is admitted to a system;

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† In order to have a brief expression for the capacity which depends on the aperture-equivalent of objectives, the author uses the term "delineating power." The word "resolving-power," as applied in England, is too restricted in meaning; the general idea being that it aims merely at the depiction or non-depiction of striations, field-markings, and similar things. Resolving-power in this restricted sense is the *particular* exhibition of the general aperture-function on *periodic* structures, whose diffraction groups consist of a number of *isolated* beams (maxima of second order) around the direct beam (which is the maximum of first order according to Fraunhofer's terminology).

The other term "definition," by which some microscopists convey the idea of a more general optical virtue of the objectives, is better reserved—as is done in Germany—for denoting the "defining quality," or the more or less perfect collection of *all* admitted rays to *sharp* foci. This quality—which at all events requires some definite name—is based on the purely dioptrical perfection of a system (the good correction of spherical and chromatic aberration, &c.). It is exhibited by the *distinctness* of all elements in the image, *large as well as minute*, and has, of course, nothing to do with aperture. An objective may possess the best definition, but nevertheless a low delineating power, if its aperture is relatively small. On the other hand, the *actual* manifestation of a *great* delineating power, or the *utilization* of a great aperture, must evidently require *good* definition, just as it requires a certain amplification. Otherwise the minuter elements which *could* be delineated by means of the wide aperture-cone, would be obliterated by the circles of indistinctness in the image, just as they would remain *invisible* with lack of amplification.

nor is it so in regard to the very essence of microscopical performance, the delineating power of objectives. This, however, does not of course exclude the idea that there might be some *other* element in the performance of the Microscope, which does not depend on the aperture-equivalent, but rather depends on the *angle* of aperture *quâ* angle; and if such an element should be found, and should prove to be of any practical importance for microscopical vision, the angular aperture would also deserve attention. Down to more recent times there has always been an opinion among some microscopists in England that such an element exists—that there *is* something in the operation of the Microscope, in regard to which the wider *range of obliquity* of the admitted rays attendant upon a wider aperture-angle, is an advantage.

The question, whether there *is* such an x—which is called by the names of "angular grip," "all-round vision," and similar expressions—or whether there is not, can surely be settled at once in a purely practical way. If it be not a mere outcome of imagination, it must be possible to demonstrate it in the Microscope with actual preparations—in the same way as the increase of opening, or the increase of light, or the increase of delineating power with the greater aperture-equivalent can be shown.

There is evidently ample range for doing this. The width of the angular grip is certainly greater in a wide-angled dry lens than in an objective of 90° balsam-angle; and it is certainly cut-down more and more, when with one and the same objective preparations are observed in water, balsam, and say monobromide of naphthaline successively. If now the angles, *quâ* angles, are effective in *any* way, *something* must be *lost*, if we change the conditions of the observation in the direction indicated above, and *something* must be *gained* in the other direction, other circumstances being the same. *What* is the benefit of the complete all-round vision of a dry lens of 170° aperture-angle against a moderate-angled immersion glass, and *what* is lost by observing an object in balsam instead of air?

No microscopist has yet demonstrated this x. Of course, when an object whose own refractive index is not much different from 1·5, is imbedded in balsam, the radiation of this object, and particularly the intensity of the diffraction effect of its structure, is changed, and may be totally obliterated; and thus it may happen that the observation of it becomes much more difficult, or the image even entirely lost. But *such* a loss is at once recovered when we substitute for the balsam a substance of much higher refractive index, although the angle is now *still more* cut-down.

The above considerations are sufficient for establishing the non-existence of a peculiar operation of the angle *quâ* angle in the Microscope. The question may be settled, however, more exhaustively by tracing the suggestion back to its true origin. This is certainly not to be found on any grounds of observation, but rather on those of speculation and analogy. Microscopists have adhered to the angles not because a peculiar benefit from a greater range of obliquity at the object has been *found*, but because such a benefit is *supposed* to be an inevitable necessity with regard to the facts of ordinary vision. The prominences of a wall are seen more distinctly in an oblique direction, or when an oblique incidence of rays makes them project their shadows. It is *supposed* that in the Microscope a similar effect must also be connected with oblique vision and with oblique incidence of the illuminating beams, and that consequently a wider range of obliquity in the aperture-cone *must* be a benefit in microscopical vision, even though we may not be able to observe it directly. This opinion, moreover, *seems* to have a strong support in the well-established fact that in many objects we see minuter details with an oblique incident pencil than we can see with the same lens by means of direct light. Moreover, with a wider aperture-angle there is a greater *variety* of the directions under which delineating pencils emanate from the object; and it is *supposed* that the greater variety of perspective aspects which seem to combine in the microscopical image must tend to the exhibition of the structural details, and enhance the impression of *solidity* in the image in a similar way as is done by binocular vision, and the more so as the objects are closer to the observer and the angle formed between the eyes is increased. By the expression of "all-round" vision the idea is suggested that in observing objects with wide-angled lenses a hundred eyes are arranged around the preparation, and join their different views of the same object in the microscopical image. These benefits, if they exist, must, of course, depend on the angles *quâ* angles, and not on the aperture-equivalents.

These suggestions reveal a very contented view of the peculiar operations of wide apertures. But it is necessary to say that all these opinions belong to the venerable relics of the past naïve period of microscopical science, which was characterized by an unshaken conviction in the validity of the hypothesis that microscopical vision is in all essential respects the same thing as ordinary vision, that is, governed by the same laws, and based upon the same conditions as those revealed by the optical phenomena with any *large* bodies. The investigation into the subject of microscopical vision, which the author began some years ago with his friend Dr. Zeiss, and has continued ever since, at once disproved this hypothesis by the exhibition of irreconcilable facts, and proved that it is in direct contradiction to the best-established principles of physical optics.

The observations and experiments mentioned in my first paper (of 1873) establish the fact that, in so far as aperture is *effective* in microscopical vision, we have nothing like shadow effects or other indications of *solidity* in the image. The advantage of oblique illumination is shown to be *solely* based on the fact that with an oblique incident beam, diffraction beams can be taken-in by the objective which are lost for the same aperture with a direct pencil. It has been ascertained by various experiments that the peculiar effects which arise from oblique illumination are *always* manifested, even if the objects, from their well-known structure, cannot possibly admit of shadow or similar effects. Moreover, it has been directly shown that the benefit of this kind of illumination by no means depends on obliquity *quâ* obliquity. For if it were so it would necessarily involve the consequence that the same benefit must be obtained by means of a direct pencil if the preparation were *inclined* to the axis of the Microscope. The fact, however, is, that when we have a structure (of any kind whatever) which is *not* depicted in the ordinary position with direct light by an objective of given aperture-angle, say 40°, it is *never* depicted by that objective when the object is inclined at any angle, *even if it is depicted in the former position by another objective of slightly increased aperture only.*

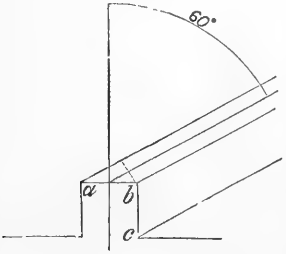
Apart from all experiment, the first principles of undulatory optics lead to the same inference. The laws of rectilinear propagation of the luminous rays, of reflection and refraction, are not *absolute* laws. They arise from and depend on a certain *relation* between the wave-lengths and the *absolute* dimensions of the objects by which the luminous waves are intercepted, or reflected, or refracted. They do not hold good unless these objects represent *large* multiples of the wave-length. With minute elements, measuring a fraction of λ, or a few wave-lengths only, we have nothing like shadows or similar effects of solidity (and nothing like prismatic or lenticular refractions), for the same reason that we have no perceptible *acoustic* shadow behind the trunk of a tree, except for notes of a very high pitch. Luminous as well as sonorous waves go all round obstacles whose dimensions are not large multiples of their own length.

The suggestion of a peculiar efficiency of obliquity in microscopical vision, taken from the analogy of oblique vision and oblique illumination in ordinary visual observation, is thus devoid of any sound basis.

Regarding the other suggestion, illustrated by the analogy of the 100 eyes around the object, this also has some very weak points. Particularly, it overlooks one little difference. Suppose these 100 eyes to be simultaneously used, and to receive on their retinas the 100 different aspects of the object; and suppose, now, all these various images *collected upon the same retina*—as is done in the Microscope; then you will conceive *what* would be the benefit of such all-round or solid vision. In the same degree as there would be a real difference among the various images, in the same degree the *total* image would become more and more confused, and would at all events show less than any *one* of the partial images could have exhibited. The single fact that we obtain distinct and well-defined vision by means of wide apertures, and that for the observation of very minute structures such wide apertures are required, at once disproves the notion that their effects depend on such circumstances as solid vision with the naked eye or with the binocular Microscope. Whenever we have the advantage of solid vision, owing to a different perspective projection of different images, in the Microscope or otherwise, this is solely because these different images are seen by *different* eyes.

There is, however, still another point of view under which the essential difference between wide-angle vision in the Microscope and variety of perspectives in ordinary vision becomes very evident. Suppose for a moment that there *did* exist a different perspective of a microscopical image by axial and by oblique rays, *similar to that in ordinary vision;* and suppose a minute cubical prominence *a b c* (Fig. 113) on an object to be observed by a wide-angled objective allowing an obliquity up to 60°. If it were true that the oblique beams project both faces *a b* and *b c* of the cube, whilst direct beams depict *a b* only, it must certainly be just as true that the face *a b* must be seen *shortened* by the oblique rays in the proportion of 1 : 2, as it of course is in ordinary vision. But what is true for the small facets of a minute ridge must also be true for any larger portion of the field. Under the above assumption, any larger object, as a *Pleurosigma* scale, ought to appear shortened, and the markings *closer* together by 1 : 2, in the direction of incidence of a pencil of 60° obliquity; or, in other terms, the objective ought to yield only *half its amplification* in that direction.

FIG. 113.



No microscopist has ever yet observed such a thing; and if it did exist, microscopical vision even with very moderate apertures would be entirely destroyed. In point of fact, the *identity* of power or amplification with *all* obliquities embraced by the aperture-angle is the essential criterion of an *aplanatic* system; and the law of convergence of the rays at conjugate aplanatic foci which was applied for the determination of the aperture-equivalent, is, as has been deduced by the author, the necessary and sufficient condition of *identical amplification* in wide-angled systems, without which no image could be delineated by such systems.

This consideration shows that the diverse obliquities of the rays in a wide-angled system cannot give rise to anything like all-round vision, because in the Microscope there is no difference of *projection* connected with different obliquities.

In the binocular Microscope we have, as a matter of fact, a diversity of images which are depicted by pencils of different obliquities at the object; and this, it is true, is a *certain kind* of perspective difference. As, however, the above observations show, even in this case the circumstances must be, in essential respects, different to those of ordinary vision. One important element of solid vision with the naked eye, the perspective *shortening* of lines and surfaces by oblique projection, is entirely lost in the Microscope; there remains only the other element, a relative displacement of consecutive planes in the image, which, of course, is still competent to afford sufficient indications for a stereoscopic coalescence of the impressions. But the fact that these displacements are seen in the Microscope depends upon a peculiar property of microscopic amplification, which by itself is a strong contrast to macroscopic vision; for this visibility depends entirely on the fact that the amplification of the depth is largely exaggerated—is always the *square* of the linear amplification in the other direction reduced in the proportion of the refractive index of the medium in which the object is.

Taking regard at the same time to the general inferences from undulatory optics, referred to above, it is seen that solid vision—i. e. delineation of objects *like* solid objects—is confined, even in the binocular Microscope, to relatively coarse elements, the dimensions of which are large multiples of the wave-length. Whenever elements *require*, for being delineated, the utilization of oblique rays, that is, of wide (and even moderate) apertures, the *arrangement* of such elements within a solid space of sufficient dimensions may be seen still with the characteristics of solid vision, but the elements *themselves* are no longer depicted as solid objects of larger dimensions would be depicted. A *Pleurosigma valve* may be seen as a solid object, by an unconscious stereoscopic impression in the binocular Microscope, or by a mental combination of the images of successive planes in the monocular; but the *corpuscules* which compose the valve can never be seen as solids, unless we could obtain objectives of a numerical aperture at least = 8 or 10, and could discover an imbedding substance of the same refractive index, in order to gain an image by means of rays of 8 or 10 times *shorter* wave-length.

The very first step of every understanding of the Microscope is to abandon the gratuitous assumption of our ancestors, that microscopical vision is an *imitation* of macroscopical, and to become familiar with the idea that it is a thing *sui generis*, in regard to which nothing can be legitimately inferred from the optical phenomena connected with bodies of large size.

VIII.—*On a New Species of Hydrosera* (*Wallich*).

By Henry Stolterfoth, M.D.

(*Read* 11*th May*, 1881.)

Plate V., Figs. 2 and 3.

A short time since I received from a friend a small quantity of a sub-peat fresh-water deposit from New Zealand. This material proved most interesting, and contains forms differing considerably from any found in Europe. Many of these have been already described by Mr. Kitton and others. My attention was arrested by a curious three-lobed form, which I could hardly recognize as a fresh-water diatom. It was not abundant, only one or two valves on a slide, and it was not till I obtained a front view of the valves that I was certain that I had a diatom.

I have placed it in the genus *Hydrosera* as the nearest I could find, although as to certain particulars it does not altogether agree with the genus as described in Pritchard's 'Infusoria,' 4th edition, p. 852; still in many respects it resembles *H. triquetra* (Wallich).

Description of Species.

Hydrosera tricoronata n. sp. Filamentous. Front view of valves nearly quadrangular, showing four ridges and a deep central depression, distinct connecting band; side view trilobate, each lobe having three projections or minor lobes. The lobes are finely dotted, no regular markings on the central hexagonal portion (cf. Figs. 2 and 3).

Habitat.—North Canterbury, New Zealand, in a sub-peat fresh-water deposit. The exact locality not known.

SUMMARY

OF CURRENT RESEARCHES RELATING TO

ZOOLOGY AND BOTANY

(*principally Invertebrata and Cryptogamia*),

MICROSCOPY, &c.,

INCLUDING ORIGINAL COMMUNICATIONS FROM FELLOWS AND OTHERS.*

ZOOLOGY.

A. GENERAL, including Embryology and Histology of the Vertebrata.

Development of Petromyzon (the Lamprey).†—Mr. W. B. Scott's paper on this important subject is divided into five parts. In the first, in which his own observations are not numerous, he deals with the maturation of the ovum, and points out that if Calberla's results are correct, *Petromyzon* differs from all other vertebrates by the following characters:—(1) No part of the germinal vesicle is extruded from the egg, and the greater part passes into the ovarian nucleus; which (2) is uncommonly large, and consists of various parts; (3) there is a great difference between the size of the nucleus of the ripe and of the unripe egg; (4) the germinal vesicle is said to become part of the ovarian nucleus long before the egg is ripe.

The second part deals with the cleavage period and the formation of the germinal layers; Schultze and Owsjannikow believed that cleavage was complete, while Calberla found that the orifice of the micropyle became converted into the first cleavage-groove, and that the result of this division is the formation of two unequal spheres. As usual, the smaller sphere and its products divide more rapidly than the larger, round which in time they grow. Mr. Scott does not find that two unequal spheres are constantly developed. The cleavage cavity is at first noticeable on account of its great size; it becomes smaller during the invagination period, and appears to be covered by a layer of cells, which do not belong to the ectoderm, but to the mesoderm or the endoderm; this is different to what obtains in most holoblastic eggs.

The gastrula is formed by a true invagination, which, however, is

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* The Society are not to be considered as responsible for the views of the authors of the papers referred to, nor for the manner in which those views may be expressed, the main object of this part of the Journal being to present a summary of the papers *as actually published*, so as to provide the Fellows with a guide to the additions made from time to time to the Library. Objections and corrections should therefore, for the most part, be addressed to the authors. (The Society are not intended to be denoted by the editorial "we")

† Morph. Jahrb., vii. (1881) pp. 101–73 (5 pls.).

not central as it is in *Amphioxus*, and by the overgrowth of the smaller elements; the first part which now becomes evident is the head, which is formed by a shallow depression of the ectoderm just below the blind end of the archenteric cavity. The layers of the upper half of the egg are formed by invagination and proceed from behind forwards. The ectoderm and endoderm lie close to one another in the dorsal median line, and on either side of this there appear large irregular aggregations of cells, which are intercalated between the ectoderm and endoderm; the mesoderm, therefore, so far as its dorsal and larger portion is concerned, also arises by a process of invagination, and it has just the same relations as in the Selachii and the Triton. The mesodermal cells increase very rapidly in the dorsal lip of the blastopore and form a continuous plate in the middle line. Shortly after this the germ-layers are developed in the ventral and lateral regions, by the growth of the smaller blastomeres; the mesoderm of this part owes its origin to a differentiation of the yolk-cells; but, as the yolk-cells in this creature belong to the endoderm, it follows that in *Petromyzon*, at any rate, the ventral mesoderm is formed from the endoderm.

At about this period the ectoderm consists of cylindrical epithelium-cells, higher and more delicate in the dorsal median line; the cells of the invaginated endoderm are likewise cylindrical, but are generally larger. At this period, too, the cells are all fitted with yolk-granules, so that it is difficult to see their boundaries; this arrangement persists until the latest stages, when many parts of the organism are completely free from granules. As the author points out, the mode of formation of the germ-layers is very similar to what obtains in the Triton, and can, without difficulty, be brought into agreement with the history of the same parts in the Selachii.

After a discussion and comparison of his results with those obtained by other observers on allied animals, Mr. Scott passes to the endoderm. Commencing with the *chorda dorsalis*, he shows that, at the conclusion of the invagination process, the embryo is bilaminate in its dorsal middle line, and trilaminate at the sides; the only exception to this arrangement being the upper lip of the blastopore into which the mesoderm is continued. There is a single layer of ectodermal and a similar single layer of somewhat larger endodermal cells in the middle line; soon there appears the first rudiment of the dorsal medulla, and, at the same time, there is seen a layer of delicate cells which separates the endodermal cells of either side from a median aggregation of cells. This last is the first rudiment of the notochord; the constituent cells become higher and narrower, and get separated off from the archenteric cavity by the down-growth of the adjacent endodermal cells. Very rapidly there appears a prismatic solid cord consisting of a single layer of cells, extending through the whole length of the body, and distinctly marked off. The chordal cells next divide and give rise to a number of irregular smaller multi-angulate cells, which take on a radial arrangement. Soon the cells lose their yolk and become vacuolated; the anterior end now becomes bent down at right angles. The author observes that the endodermal origin of the notochord, first described by Balfour for the Selachii, has now been seen in *Amphioxus*, *Petromyzon*, the Teleostei, Urodela, Lacertilia, and Mammalia. So too in the Tunicata the chorda is of endodermal origin; and, on the whole, Balfour's view is completely substantiated. The archenteric cavity, which primitively arises by invagination, is partly converted into the permanent digestive canal, and is partly constricted off. The fore-gut is early differentiated into an anterior pharyngeal and branchial portion, while the hinder part gives rise to the liver, heart, and head-kidneys. In the former region the first differentiation is the development of the branchial clefts, which arise as endodermal diverticula, dividing the mesodermal plates of the head and passing to the ectoderm. Eight pairs of clefts become developed; the first pair disappears altogether, and the embryonic arrangement found in the Selachian *Heptanchus* is consequently highly primitive; to the hypothetical stem-form with eight clefts we may apply the term of *Octotrema*. The arrangements seen in *Petromyzon* afford no support to the supposition that any vertebrate ancestor had gill-clefts in front of the present first pair. So again, the mouth, which is a depression of the ectoderm, would appear to be the primitive vertebrate mouth; there are no indications of any other, and there is no outpushing of the endoderm, by which process a mouth must have been formed, if it has not arisen from a depression of the ectoderm.

The only glandular organs found in the embryonic lamprey are the liver and the thyroid, and they are by no means well developed.

As organs developed from the ectoderm we have (1) the integument, which during the whole of the embryonic life is unilaminate; its cells are high and somewhat irregular in form; they are strikingly similar to those found in the Triton at the same period, but are not so regularly arranged. Further observations confirm the view that the upper germ-layer primitively has its cells in a single layer. (2) The central nervous system. Here the author finds himself in agreement with Calberla, whose observations, however, were confined to the earlier stages. Although the medullary tube exhibits a different development in *Petromyzon* to that which is seen in other vertebrates, the difference is only apparent. In the higher vertebrates (the Teleostei excepted) the medullary tube is formed by the development of two folds, which grow together and so enclose a canal. In the lamprey the folds are appressed, and the medullary tube forms an inwardly projecting knob, which, when it is separated off from the ectoderm, is at first a solid tube, and only becomes hollow by the outgrowing of its cells. As in the Selachii (Balfour), the wall of the brain is, at first, everywhere equally thick, and there are no special thickened or thinner regions. The first sensory organ to appear is the auditory, and it lies just in front of the first primitive vertebra, and is not, as in the Selachii, separated from it by some distance; but it is to be noted that in the lamprey the whole brain is exceedingly small. One of the most striking peculiarities in this organ is that for some time there is no tendency to folding; when it does occur it appears to be due to the sudden increase in growth of the median portion. Owing to the mode of life of the larva the fore-brain long remains proportionately very small. The rudiment of the olfactory organ is primitively single, and not, as stated by Calberla, double.

The mesoderm gives rise to some of the voluntary muscles, the dermis, a large part of the intramuscular connective tissue, part of the peritoneal membrane, from its outer layer; and from its inner to the greater part of the voluntary muscles, the axial skeleton, the musculature and connective tissue of the heart and enteron, and to a large part of the peritoneal membrane; as well as to the uropoetic system. In this last, which alone we have space to notice, there is considerable agreement with what is seen in the Amphibia, both of which appear to have retained ancestral arrangements, while the higher Selachii have entered on a new line of development. It is important to note that the infundibula of the head-kidney are metameric; in the very earliest stage after the appearance of the lumen there are two simple ducts, which open into the cœlom. This first stage probably corresponds to a condition that has been inherited, and calls to mind the account given by Bütschli of the same organs in the Platyhelminthes. In the second stage, that of the true head-kidney, the first development of the excretory apparatus of the true vertebrate is seen; the oldest openings are the furthest forward, just as the head is the oldest part of the organism. For a long time the head-kidneys are the sole excreting organs of the larva, and the number of infundibular orifices at the time when it escapes from the egg may be five, but are ordinarily four.

Origin of Colonial Organisms.*—Dr. A. Wilson considers that (1) the original condition of organisms is "colonial." The universal segmentation of the egg is a proof of this inference, and the development of new forms by this so-called process, in low forms like Gregarinæ, &c., supports this conclusion. (2) The lower we proceed in the scale of being, the more marked is the tendency to form "colonial" organisms. (3) Arrest of development, by causing an organism to cease progressing at a segregated stage, will tend to produce a "compound" and "colonial" constitution. (4) The plant world is "colonial" in its highest types. Plant-development has not proceeded towards any marked increase of "individuality" over the colonial nature of lower forms. A tree is in many respects as markedly "colonial" as a *Volvox*. (5) The highest animals exhibit lingering traces of an originally "colonial" nature in their histological composition. (6) The tendency of life-development is towards concentration and the conversion of the "colony" into the true "individual."

It is suggested, by way of final inference, that the theory and idea of an originally "colonial" constitution may explain the existence, in man and higher animals generally, of those tribal and family associations which mark the upper strata of existence. The semi-independent action of many parts of the higher brain, for instance,

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* Lecture at the Royal Institution. See Ann. and Mag. Nat. Hist., vii. (1881) pp. 413–16.

receives an explanatory hint as to its causation, from the idea of an originally independent and colonial constitution.*

Ear of Ganoids.†—Herr A. Cisow has studied the structure of the organ of hearing in two species of sturgeon, besides the sterlet. His figures are taken chiefly from the latter. He sums up his results as follows:—

1. The membranous labyrinth essentially resembles that of osseous fishes. This resemblance extends to microscopic details.

2. The endolymphatic duct arising from the sacculus runs into a cæcal endolymphatic sac. In the Plagiostomi, as both Weber and Retzius have shown, canals proceed from this sac towards the surface of the skull.

3. There exist *papillæ partis basilaris*, like those discovered by Retzius in osseous fishes.

4. The author does not share the views of his predecessors as to the structure of the wall of the labyrinth. Hasse, Retzius, and Kuhn describe its tissue as fusiform cartilage (*Spindelknorpel*). He compares it to the cornea, like which it has juice-passages, and within these a reticulum of protoplasmic bodies. The ground-substance contains connective-tissue fibrils, best displayed by means of trypsin-digestion.

5. The neuro-epithelium is similar on all the *cristæ* and *maculæ acusticæ*, as well as on the *papillæ partis basilaris*. It is monoderic, and consists of two kinds of cells, differing in form. The *cylinder-cells* lie between the peripheral processes of the *fibre-cells*. The cylinder-cells have granular protoplasm; about the region of the oblong nucleus, with its brilliant nucleoli, the cell is somewhat inflated. The surface of the cell often displays a fine longitudinal striation. The free ends of these cells are often protected by a clear cuticular selvage, stretched continuously from cell to cell. From this border, just above the middle of each cell, arises a long auditory hair, having a broad base, and tending to become resolved into fibres towards its point. The inward opposite extremity of the cylinder-cell extends to about half the depth of the epithelial layer, where it usually ends abruptly. As to the fibre-cells, their form differs according to the position of the nucleus. If the nucleus lie midway in the cell, the latter is fusiform: this is M. Schultze's fibre-cell, with peripheral and central processes. The peripheral process reaches to the cuticular border; the central process has its somewhat expanded end inserted on the basal membrane of the wall of the labyrinth. If the nucleus lie towards the deeper end of the fibre-cell, the conical body of the cell rests directly upon the basal membrane. These cells have but one (peripheral) process, and answer to M. Schultze's basal cells. As with the other cells, this process extends to the cuticular border.

6. The nerve-fibres enter the epithelial layer, either as axis-cylinders protected by their sheath, or they retain at first Schwann's sheath together with the medullary sheath. Without dividing, they pass by

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* Cf. also M. Perrier's remarks, this Journal, iii. (1880) pp. 592.

† Arch. Mikr. Anat., xviii. (1880) pp. 486–519 (2 pls.).

the central processes of the fibre-cells and their nuclei. At the level of the deeper ends of the cylinder-cells the axis-cylinders divide. The medullated fibres lose their medullary sheath and assume a horizontal direction, soon dividing and anastomosing with the neighbouring bundles of fibres. There is thus formed, beneath the cylinder-cells, a plexus of pale nerve-fibres. From this plexus arise fine bundles of fibres, which trend towards the deeper ends of the cylinder-cells, and then course along their surfaces to the cuticular border, but do not perforate the latter.

Thus the fine fibres investing the cylinder-cells are to be interpreted as a terminal nervous apparatus, while the cells are mere supports for the nerves [?].

Fauna of the Austral Regions.* — M. Alph. Milne-Edwards gives in this paper an instalment of a large work in the hands of the French Academy of Sciences, on the present geographical distribution of animals. He refers chiefly to the superior animals of the land and sea, but takes account also of the lower forms, and while comparing them with forms found elsewhere, seeks for physical or other circumstances capable of explaining their presence at, or absence from, this or that part of the globe.

He considers, from the facts of geographical zoology, that in most cases the hypotheses which seek to explain the diversity of organisms by the modifying influence of climate and other conditions, combined with the struggle for existence and working through natural selection, are insufficient for the purpose.

In putting forward some general views suggested by the study of the subject, he takes occasion to define the terms *species*, *variety*, and *race*.

"The characters of a *race*," he says, "are decided by the result of two forces whose directions may be either parallel and similar, or diverging and even opposite. One of these forces is *atavism*, or a tendency on the part of the being which is in course of development to realize the structural forms of its ancestors, and to become a faithful image of them. The other is the power of biological adaptation, that is to say, the tendency of the living being to become modified when the conditions to which it is subjected happen to alter." He regards the fact of hereditary transmission of certain powers and structural peculiarities as fully proved, and as probably depending on the nature of the structure of the organs concerned. Similarly, the descendants of common ancestors may vary considerably with differences of climate, food, &c., and thus form races. But the power of atavism is greater than that of these influences, and it increases with the number of generations which follow each other under similar external conditions. The power of adaptation does not thus increase, and is very limited for single individuals; but it may, in conjunction with the working of atavism, when this coincides with it, after many generations become cumulative and produce a steadily increasing effect on the zoological characters of a species.

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* Ann. Sci. Nat. (Zool.), x. (1880) Article No. 9 (4 pls. and a map).

But such variations do not alter the type, e.g. the horse, whose races persist and do not run into each other, but are nevertheless known to be of common origin.

With regard to *species*, two kinds must be distinguished: "There are *primordial species*, that is to say, species whose origin cannot be attributed by the method of analogy to ancestors of another organic form, whose type has no other representative in the present condition of things; but there may also exist *derived* or *secondary species*, that is to say, races of individuals which remain distinct from each other, and are characterized by invariable structural peculiarities, but which differ so little from one another that one is right in regarding them as sprung from one identical stock." The latter are also here called *permanent races*, and the secretary-bird, the giraffe, and man, are given as instances of the first case, many so-called species in the pigeon and dog genera are cited for the second, as being of no greater specific importance than local varieties. The author considers that, on the one hand, writers who have looked on all species as primevally established, have multiplied species to an inadmissible extent, simply on the ground of the differences seen to exist between them at present, no account having been taken of the unequal capacity for variation exhibited by different forms; while their opponents have exaggerated the importance of the principles under which species vary, and have thus drawn unauthorized conclusions as to the origin of the present state of the animal kingdom.

A most important principle is that the older a race is, the less it has been mixed with other races; and the less alteration of locality it has undergone, the more stable are its characters. For species as well as races must have had their beginning, and they have their periods of youth and mature age; they appear by analogy to be modifiable in different degrees; and thus one exposed to various influences in its early stage would vary when an older and more fixed type would remain constant. Thus a species soon after its origin would, if its members were scattered over different localities, give rise to special races or *derived species*, which might, if kept in their localities, become fixed and assume the condition of primordial species.

Of causes which tend to keep races of a species distinct are mentioned, difference in size, and difference in the period of sexual activity; also any modifications undergone by accessory parts of the generative apparatus, as the excitant odoriferous glands. Other modifications, such as those of the colours of the tegumentary system, and the proportions of parts of the body, produced by altered conditions, have less zoological importance, for they may vary in different individuals. But the varieties produced will always be more numerous the more widely the species is distributed; special attention, in dealing with geographical zoology, must be paid to difference or similarity existing between the species of the fauna under study and those of other regions.

The more special observations are entitled 'Memoir on the Fauna of the Antarctic Region.' First Part. Preliminary Considerations (noticing briefly the physical conditions of the district); and Second

Part. Avian Fauna of the Antarctic Region (dealing at length with the *Impennes*, or penguins, in their geographical and zoological relations).

Zoological Results of the Barentz Expedition.*—In a volume of rather more than 100 pages, illustrated by seven plates and a map, Drs. Horst, Hoek, Noman, Hubrecht, and Jentinck, give an account of the Annelids, Pycnogonids, Lamellibranchs, Fishes, and Mammals collected by the above expedition to Barentz Sea.

Fifty-one Annelids belonging to twenty-two families were collected, but none of these were new to science. Of the Pycnogonids, *Nymphon Sluiteri* is a new form, which was represented by a single specimen. A full account and a figure is given of *Colossendeis proboscidea* (Sabine) which has lately been described by Mr. Miers (from Mr. Leigh Smith's collection) as *Anomorhynchus Smithii.* The body is " highly concentrated," and it is interesting to note that the regular windings of the cæcal processes of the intestine may be seen through the chitinous coverings of the legs into which they enter.

Pecten lucidus and *Cardium fragile* are the two new Lamellibranchs; the author of this portion of the report enters into some anatomical details, and, among other points, describes some special structures which were found between the epithelial cells of the tentacles of *Lima elliptica;* these are either rod-shaped filamental cells with a swelling on either side, or are knob-shaped. The enlargements on the former bodies lie, on the outer side, at the level of the epithelium, and on the inner side between the epithelial layer and the connective tissue, or within the latter; they are connected by a fine filament with the nervous tissue. The other bodies have their swollen ends projecting outwards, and are continued by a more or less long rod-shaped portion into the internal cell-layer. A transverse section of a tentacle reveals a nerve with a number of nerve-cells in its middle axis, whence the nerve-fibres radiate out in two directions.

The afferent orifice of the pallial cavity in *Modiolaria discors* is described as being half closed by a membrane; on the inner side of this partition there are two muscles, one of which draws the wall in and out, while the other acts as a constrictor. The generative organs of this species are largely placed within the mantle, as in *Mytilus edulis.* The mantle of the new species *C. fragile* is transparent, and colourless, save at its edge where it is a little thickened and yellowish; the afferent and efferent tubes are provided with cirri, which again are beset with fine papillæ, formed of large cells and richly pigmented at their tips.

After some notes on the digestive tract of the specimens examined, the author turns to the branchiæ. He recognizes the filamentar structure of the gills of *Pecten grœnlandicus*, and finds that those only which belong to the two median lamellæ are fused at their upper ends with one another. On either side of the filaments there are long strong hairs which catch in those of their neighbours; but there are no interlamellar connections as there are in *Mytilus* and *Arca.* In

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* Niederl. Arch. Zool. Suppl. Bd. i. (1881).

addition to these hairs, there is at the lower end of a pair of filaments a small round spot where the epithelial cells carry stiff hairs. The blood-vessel within the filament is divided into two halves by a septum.

The author directs attention to Bonnet's division of the gills of Lamellibranchs into (1) filamentar, (2) lamellar, (3) folded, (4) "coulisse"; these four groups form a scale which increases in complexity, but the divisions do not agree with any other division of this class; species belonging to the same family are found in the most widely separated groups, and species of different families present just the same arrangement of gills. This is illustrated by a table and by various examples; as also by a preceding detailed account of the branchial arrangements of *Modiolaria discors*, *Arca glacialis*, and *Astarte sulcata;* in this last form the outer lamella of the inner and the inner lamella of the outer gill, contain venous blood, while the other two lamellæ contain arterial.

B. INVERTEBRATA.

Mollusca.

Digestive Organs of the Dibranchiate Cephalopoda.*—In this essay Dr. C. Livoro is principally occupied with histological details.

The two lips are described as having very much the same structure, and as being made up of epithelium, connective tissue, and muscular fibres. On the free edge of the upper lip the first of these has not pavement, but polyhedral cells, similar to those which are found in racemose glands. Where the lips unite the epithelial cells are cylindrical in form, and this kind is found over all the lower lip, save that on its inferior surface there is a horny cuticle, without any definite structure. The muscular fibres are radial or circular. The jaws are likewise inferior and superior, and are moved by powerful muscles; they consist of two solid convex and concentrical layers which unite in front to form the free cutting edge. The greater part of the so-called buccal bulb is made up by the muscular masses which move the jaws. The tongue is only free in its anterior portion, and this is furnished with papillæ which are apparent to the naked eye; the constituent muscular portion is covered by a papillate mucous membrane, the epithelial cells of which are cylindrical, and invested by a cuticle which presents at certain points small horny papillæ, comparable to the denticles which are found on the radula. This last is a solid cuticular plate, which is found on the surface of the tongue, in its posterior region. The denticles on it are directed backwards. The horny substance is homogeneous, and the epithelial cells are cylindrical. Behind the radula there are two *lateral masses* of an irregularly pyramidal form, which touch one another in the region of the pharynx, and then unite into a single mass. They abound in connective tissue, in the midst of which a section reveals muscles passing transversely, obliquely, or longitudinally. The inner upper, and two-thirds of their outer surfaces are invested by a cylin-

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* Journ. Anat. et Physiol. (Robin), xvii. (1881) pp. 97–123 (2 pls.).

drical epithelium and a cuticle, the surface of which presents spiny prolongations. On the upper surface there are papillæ, and on the lower portion of the outer face the cuticle disappears, and there are seen large papillæ covered by an epithelium and large glandular cells. The submandibular gland, which the author believes he is the first to describe, is situated immediately behind the lower jaw; it is oval in form and its long axis runs antero-posteriorly; racemose in appearance, the acini are separated by connective tissue arranged in delicate layers; some of the acini contain polyhedral cells, the protoplasm in which is granular; others have the epithelium cylindrical, and these appear to be sections of the collecting ducts. The author has no opinion as to the function of this organ. The salivary glands are well developed, and consist of two pairs; in structure they are very similar to the salivary glands of the higher Vertebrata, and the author even compares the duct to the Stenonian canal.

The œsophagus presents numerous longitudinal folds of the mucous membrane, and the same structure is found from the mouth as far as the gizzard or true stomach. Perpendicular sections of the wall reveal the presence of, from within outwards, a cuticular layer coloured yellow by picrocarmine, a layer of cylindrical epithelial cells arranged in a single row, a mucous layer containing connective-tissue and elastic fibres, and adapted to admit of the extension of the walls of this region. The succeeding muscle is arranged in two layers, one circular and one longitudinal, and in the non-distended condition this portion appears to be thicker in the region of the crop than in that of the œsophagus; then comes another layer of connective tissue, which supports a simple layer of pavement epithelium, and these are regarded by the author as analogous to a peritoneum. The gizzard has very thick walls, its inner surface is deeply grooved, and a hard plate is to be found in the centre of the anterior and posterior faces. The thick lining cuticle may, as in birds, be removed in a single piece; it exhibits no solution of continuity, and there are no glandular orifices to be detected in it; the striated appearance is due only to its mode of formation, as it is absolutely structureless. The glands were found in the subjacent epithelium, and the exact function of the organ is made apparent by their absence. The muscular layer, some of the fibres of which take a vertical direction, makes up the chief part of the walls. Vibratile cilia were detected on the cells of the intestine; these cells are either cylindro-conical or calyciform (these become rarer as the rectal region is reached), and the latter are the sole glandular elements which are found in the walls of the intestine.

In the neighbourhood of the gizzard there is a spiral cæcum, the internal surface of which presents the appearance of valvulæ conniventes; these are composite, their two faces being invested by smaller valvular folds; the cylindro-conical epithelial cells are ciliated, and in addition to them there are polyhedral cells which appear to belong to special glands, to which the author proposes to give the name of *valvular glands.*

The liver is very voluminous, and is not lobed; it is very soft;

in hardened sections polygonal spaces are to be seen which are separated from one another by collecting canals, into which open a number of cæca. In fact, the organ is a tubular gland, not unlike that of the crayfish; the tubes formed by a structureless *membrana propria* are filled with special polyhedral cells, varying in size and frequently containing a number of fat-granules. The investing envelope is resistent and formed of connective tissue. The author proposes to investigate how far this organ has the function of a pancreas, which it resembles in structure.

Accessory Generative Organs of Terrestrial Mollusca.*—Dr. A. Batelli's observations were carried on chiefly upon *Helix pomatia.* He confines himself as a rule to stating the bare facts.

A common membrane covers all the sexual organs and is termed *serous;* it consists of an outer connective tissue, and of an inner cellular formative layer, whose inner cells are irregularly aggregated, forming a tissue resembling the connective membrane of Kollmann; the layer is structureless and fenestrated. The cells of the connective-tissue layer are globose and devoid of cell-wall, those of the inner surface contain a dense non-vacuolated protoplasm; the exterior ones originate the connective fibres. The nerves are provided with connective-tissue sheaths, their main trunks in the serous membrane are flat and fibrillated and contain nerve-cells either singly or in ganglionic masses at certain points. Three kinds of nerve-branches are distinguished, viz. 1. *Terminal,* produced by the breaking up of a large trunk into two or three of smaller diameter; 2. *Intermediate,* given off by the main trunk, without causing diminution of its diameter — the neurilemma is continued uninterruptedly on to the branches; 3. *Derived from cells.* It is probable that elementary fibres enter these peripheral nerve-cells of the serous membrane, break up within them, and reunite at the further extremity into a fibre: the neurilemma of the cell is continued over the fibre derived from it.

Of the different organs, the wall of the *dart-sac* is composed of muscular fibres which lie chiefly on the external aspect, and of a narrow connective-tissue layer which lies chiefly to the inner side of the former, and is almost constant in thickness throughout the organ; the basal bulb is, however, chiefly muscular. Besides these, the sac is lined by an epithelium of long cylindrical cells, elongated towards their free ends, and inflated at the opposite extremity; a cuticular lamina covers the inner surface. At its posterior end the wall of the bulb is deeply plicated longitudinally, and its epithelium is in continuity with that lining the sac proper; the posterior denticles of the dart fit into some lateral diverticula of the cavity; the inner surfaces of all the cavities are, further, minutely pitted. At the anterior end the wall of the sac presents a gap below by which its cavity communicates freely with the vestibule. In addition to its internal epithelium, the connective tissue, and muscular layers, the sac has a second connective-tissue layer, covered by an epithelial one, outside

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* Atti Soc. Toscana Sci. Nat. (Mem.), iv. (1880) pp. 203–25 (2 pls.).

all. It is suspended to the top of the vestibule by a thickened band formed by this outer connective tissue.

The wall of the *multifid glands* is made up of muscular, chiefly horizontal, fibres and of connective-tissue fibres; the true gland-cells form a lining mosaic; they are cylindrical, cup-shaped epithelial cells, becoming purely cylindrical at the commencement of the excretory tube: the substance secreted by the glands is remarkably refractive and dissolves in acetic acid. The *vagina* exhibits in transverse section the same structure as the penis; the connective-tissue layer may either become continuous with the connective reticulum of the copulatory sac or form an independent zone, in any case lying just beneath the epithelium. The *copulatory sac* consists of a bulb prolonged into a filiform tube ending in an ampulla; the external wall of the bulb is muscular and consists of circular fibres immediately underlying the epithelium and of more numerous transverse converging ones, which unite with the former and with the connective fibres to form a dense reticulum; the villous interior of the bulb is lined with epithelium 0·05 mm. thick, which disappears in the ampulla. The latter organ is generally found partially filled with a concentrically stratified, nucleated substance, which may perhaps be merely the result of coagulation of the glutinous liquid which carries the spermatozoa.

The *ovispermiduct* (*uterus* of former authors) is a tube divided longitudinally into a larger groove which acts as an oviduct and a smaller one which transmits the sperm: the two grooves are in communication. The latter one receives the secretion of the tubules of a gland, called the prostate, which lies along its course. The *oviduct* proper, that is, the independent tube which leads from the common duct to the vagina, varies in its characters at different points; near the joint duct it is partially divided into two by a large longitudinal fold; as it approaches the vagina it becomes more like that organ; it differs from it, however, in having a set of tubular glands lying in the subepithelial connective tissue; they first appear only at the bottom of the groove formed by the fold, but ultimately extend to the apex of the fold and to the wall opposite to it. The lining epithelium is ciliated, its cells range in size from 0·06 mm. in diameter near the vagina to 0·03 mm. near the ovispermiduct. This organ too has glands, increasing in number backwards at the expense of the muscles, which ultimately become reduced to a few decussating fibres; the glands are conical tubes with squamous secreting epithelium, and may be well studied by the use of bichromate of ammonia or by hardening in alcohol or chloride of gold; in *Limax* they are simple cæca lined by a non-ciliated modification of the ordinary epithelium of the oviduct. In *Helix pomatia* the cells of the ciliated epithelium of the ovispermiduct are smaller than in *Planorbis*, being only 0·03–0·04 mm. long, including the cilia; their function is probably merely circulatory. The *prostate* is a racemose gland whose follicles are lined by cup-shaped epithelial elements whose nuclei are placed near their bases; the follicular cavities are small and narrow as compared with those of *Limax*; a mucous substance has been observed still in contact with the secreting cells. The uterine artery, which adheres to the prostate throughout the entire length of that gland, is covered externally by the serous coat, and consists of a layer of interlacing muscular fibres lined by an endothelium.

The *vas deferens*, leading from the ovispermiduct to the penis, is lined by a non-ciliated epithelium which is thrown into folds in *H. pomatia* (barely perceptible in *H. nemoralis*), and surrounded by a connective tissue, and this in turn by a muscular layer. The penis-sheath has thick plicated walls; in this case the folds contain connective and muscular elements; the epithelium has a surface cuticle; the folds have a very complicated arrangement in *H. nemoralis.* The flagellum has a thin broad fold, consisting entirely of connective tissue clad with epithelium, projecting into its lumen; its end is imperforate; the walls agree in structure with those of the other organs.

The *albuminiparous gland* is a racemose gland, provided with a single duct. The gland-cells are basally nucleated, and have near their margin a protoplasmic reticulum containing mucous globules; the epithelium of the ducts is ciliated; the main duct acquires muscular and connective-tissue coats on quitting the gland.

In the *efferent canal* (Baudelot), the "superior efferent canal" of Moquin-Tandon, the tube is simple, not compound; it consists of connective tissue with a few muscular fibres, and its lining epithelium varies from squamous to cylindrical in different parts; the nucleus presents the appearance (lately so widely observed in both animal and vegetable cells) of a fibrous reticulum in its interior. The tube is found filled with spermatozoa which tend to issue in a mass when it is cut through (this is probably due mainly to the movement of the spermatozoa themselves). Distilled water causes these bodies to become twisted up; potash produces a gentle oscillation, and then the filament becomes coiled up, but the outer coat is finally resolved into small granules; acetic acid causes a less active movement and a similar retraction, the tail gradually becomes less refringent under its action and disappears, the head becomes detached from the filament.

Organization of Tethys fimbriata.* — R. Hartmann endeavours to add to the numerous details of this Nudibranch's history already known, by describing minutely its movements and its appearance in life.

In crawling it expands the branchiæ, moves the lateral processes up and down, backwards and forwards; the foot undergoes considerable undulatory changes of form. The head-lobes are generally carried highly elevated, but if they are folded back or along the sides the cephalic expansion with its tentacles drawn in spreads out like a veil on the bottom, justifying the name of veil-mollusc which is applied to this animal. The mouth, lying on the body at the lower side of the point of insertion of the cephalic expansion, can be protruded on the end of a smooth papilla, and is surrounded by short, delicate tentacles. Near each of the dorsal branchiæ, in the middle line, a wart-shaped prominence is temporarily elevated when the branchia itself

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* SB. Ges. Naturforsch. Freunde Berlin, 1880, pp. 9–12.

is in the half- or unexpanded condition, but disappears when the branchia is fully unfolded. The anus, which is often widely opened, is lateral in position. The tint of the coloured spots and bands of the back, cephalic expansion, and lateral appendages is subject to great variations in different individuals; it ranges from brown to black, and varies in intensity; it may also present dull spots; the markings are however always well defined on old specimens.

Molluscoida.

Tunicata of the 'Challenger' Expedition, &c.*—Dr. W. A. Herdman has undertaken the descriptions of this collection, comprising from 150 to 200 species, the majority of which are new. The paper now published is a preliminary report on two families of the Ascidiæ simplices, viz. the Ascidiadæ and the Clavelinidæ.

The Ascidiadæ are synonymous with Forbes' *Ascidia*, and include those simple Ascidians which are as a rule (though not without exception) externally characterized by an 8-lobed branchial and a 6-lobed atrial aperture, as distinguished from the Cynthiadæ (both 4-lobed) and the Molgulidæ (branchial 6-lobed and atrial 4-lobed). Of the five previously known genera, two (*Rhopalœa* and *Rhodosoma*) are not represented; but there is a new genus, *Abyssascidia*, obtained at the great depth of 2600 fathoms. The four genera include seventeen species, fifteen of which are new.

Of the Clavelinidæ—a small group of social Ascidians—there is a new genus, *Ecteinascidia* (three species), and two new species of *Clavelina*. Dr. Herdman gives his reasons for considering that, instead of occupying a position intermediate between the simple and compound Ascidians, the group should be included in the former.

Dr. Herdman also describes and figures † thirteen species (six nov. sp.) of Ascidiæ dredged during the last three summers on the west coast of Scotland, in Loch Long and in Lamlash Bay, Arran.

Budding of Pyrosoma.‡—The question of the origin of the peribranchial spaces or *lateral atria* in the bud of this Tunicate, which baffled the researches of Huxley and Lacaze-Duthiers, has been decided by L. Joliet in favour of the mesodermic tissue which occupies the interval between the endostyle and the test.

In a transverse section of a sufficiently young bud, this tissue may be found to contain the generative rudiments, the nerve-ganglion, and two oval masses of cells which represent the walls of the peribranchial spaces; the same result is arrived at by examination of a median longitudinal section. Even in the adult the wall of the branchial sac on the neural side is connected with the epidermis by a loose tissue which is evidently mesodermic, while on the opposite side, between the endostyle and the test, lies an analogous tissue traversed by blood-vessels, and becoming a regular lamina at the posterior side. Thus the endostyle is accompanied by a tissue derived from the mesoderm which develops in the bud into the

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* Proc. R. Soc. Edin., x. (1880) pp. 458–72, 714–26.

† Journ. Linn. Soc. Lond. (Zool.), xv. pp. 274–90 (6 pls. and 3 figs.).

‡ Comptes Rendus, xcii. (1881) pp. 473–5.

aforesaid walls of the atrium. It is very remarkable that these walls should have this origin in this form; for in the *Ascidiæ* they are the result of evagination of the internal layer, though even there their really mesodermic origin appears to be indicated by the development within them of the muscles and blood-vessels.

Queensland Bryozoa.*—Mr. W. A. Haswell records twenty-seven new species (and a new genus) of Bryozoa (eighteen figured) from Holborn Island, near Port Denison and the Great Barrier Reef, the bottom, at a depth of about 20 fathoms, being apparently covered with little else than Bryozoa intermixed with Plumulariidæ and Sertulariidæ and a few shells. Bad weather prevented extended examination of this remarkable bed. The sheltering influence of the Great Barrier is probably a sufficient explanation for the abundance of the Bryozoa at so slight a depth.

The new genus (with one species) is *Sphæropora* (*fossa*), the most remarkable feature of which is the circular pit at its upper pole, always present and in the same position, and large enough to admit the point of an ordinary stout sewing-needle. It is 0·75 mm. in diameter at the mouth, and penetrates about half the thickness of the zoarium, gradually narrowing as it descends. From the description the signification of the pit does not seem quite clear, as it might either depend upon the shape of the substance upon which the zoarium has grown, or it may represent the central cell with which we are acquainted in such species as *Stichoporina Reussi* Stol., *Batopora rosula*, &c., or even the depression in *Cellepora globularis*, with which the Australian species has much in common, and we think it will be found that the specimens should be classed under *Cellepora*.

The new species belong to the genera *Crisia* (1), *Pustulipora* (1), *Onchopora* (3), *Scrupocellaria* (2), *Membranipora* (1), *Biflustra* (2), *Lepralia* (6), *Cellepora* (2), *Eschara* (2), *Hemeschara* (1), *Vesicularia* (1), *Conescharellina* (2), *Selenaria* (1), and *Myriozoum* (1).

In regard to nomenclature, we may remark that Mr. Haswell describes a species as *Membranipora cervicornis* nov., but as this name has already been used by Mr. Busk for a well-known species, it must of course be changed; *Cellepora lævis* nov. is undesirable, seeing that Macgillivray called an Australian species *C. lævis* Flem., a name used by Fleming, Blainville, Johnstone, &c., and which Mr. Busk gives as a synonym of *C. ramulosa*.

Myriozoum australiense nov. is an old and common friend from the Australian tertiary beds, where it is known as *Spiroporina vertebralis* Stol.; and Mr. Haswell will find in the recent forms (if his specimens comprise the two stages) that in one part of the branch the centre shows the characteristic spongy axis, while in other parts the cells are distinctly separated and do not meet in the centre. This stage is shown in his figure 10.

New Zealand Fossil Bryozoa.†—The Rev. J. Tenison-Woods describes a few New Zealand Bryozoa (and Corals) ranging from the

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* Proc. Linn. Soc. N. S. Wales, v. (1880) pp. 33–40 (3 pls.).

† Pal. New Zealand, pt. iv., Colon. Mus. and Geol. Surv. Dept., 1880.

Miocene to the Greensand of the New Zealand Survey. Mr. Woods uses the term Bryozoa for the first time, as he says he is not convinced by the reasons Mr. Hincks gives for using "Polyzoa," and thinks "it useless for English and a few American naturalists to withstand the universal use of Ehrenberg's term."

Under the sub-order Hydrocorallinæ he describes two species of *Heteropora*, two of *Cylindropora*, and one *Sporadopora*. It is at present somewhat bold to place *Heteropora* under the Hydrocorallinæ, for while we may well be asked to suspend judgment, we may also ask for further proof before forms having so many points in common with *Discoporella* and other Cyclostomous Bryozoa are removed to the Hydrocorallinæ. One of the forms, he says, comes very near to (if it is not identical with) the *Heteropora neozelandica* Busk, and he finds no sign of hymen-like lids in the interstitial tubes.

Under the Bryozoa nineteen species are mentioned, ten of which are described as new and the rest were previously known in other localities. Mr. Woods, following Stoliczka, places *Spiroporina vertebralis* Stol. among the Cyclostomata, while it is undoubtedly Chilostomatous and should be called *Myriozoum*, if that genus is to be based principally on the spongy character of the axis; or should not *Myriozoum* retain its present position, then it must be *Porina*. From the figure and description it is difficult to assign a place to the other *Spiroporina*, which is probably also Chilostomatous; and there is an Australian fossil with very similar mode of growth, with the oral aperture of a *Schizoporella*, surrounded with a tubular peristome.

Fossil Chilostomatous Bryozoa from Australia.*—Mr. A. W. Waters gives a descriptive list of seventy-two species of Bryozoa belonging to the sub-order Chilostomata, from a lump of clay obtained from the neighbourhood of the Yarra-Yarra River, Victoria. The specimens are fragmentary, but in excellent preservation. There are eight species of *Catenicella*, a genus unknown in the fossil state until quite recently, when Mr. B. Wilson described twelve fossil species, none of which are known living; two of the Yarra-Yarra species still live in the Australian seas, and one of these also occurs in the Geological Society's collection from Mount Gambier. Among the most interesting of the specimens is a *Catenicella*, consisting of long internodes, with a double row of cells in each internode. The short-beaded *Catenicellæ* now living have probably been developed from forms with long internodes. *Microporella* is also well represented by some interesting forms, which make it necessary to widen the definition of the genus. A very interesting *Cellaria* with subglobular internodes explains the Cretaceous fossil called *Eschara aspasia* by d'Orbigny. Of the Chilostomata found in this deposit, thirty-nine are considered new, although this number may have to be reduced; nineteen are now found living.

The author adopts the principles of classification laid down by Hincks, Smitt, and other recent writers on living Bryozoa, which he regards as preferable in themselves, and also as facilitating the comparison of fossil with recent forms.

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* Abstr. Proc. Geol. Soc. 1881, pp. 73–4.

Arthropoda.

a. Insecta.

Detonating Organ of Brachinus crepitans.*—Professor P. de Rougemont gives a careful description of the anatomy and physiology of this organ in the above species of Bombardier beetle.

He confirms in the main the account given by Léon Dufour, of what that writer terms the "preparing" and "preserving" organs. There is, however, a long, slender, thread-like body on each side, lying between the preparing and preserving organs, which was not fully described by that author; it is tubular, and twisted in all directions upon itself; when isolated and unrolled it measures from 45 to 50 mm. in length, and has the uniform width of a fine hair; it does not branch at all except where it is attached to the preparing organ, where it bifurcates, each branch entering one half of a double glandular organ. The glands are strictly anal glands; their excretory tubes, just mentioned, appear under the Microscope to be filled with bead-like globules of air; the vacant spaces which are sometimes noticed in them are occupied by air which is pushed forward. The tube really contains an inner central straight, and an outer spiral tube coiled round the former; it is this latter which generally alone contains the air. The colour of the whole is whitish; the external coat is muscular and abundantly supplied with tracheæ, the lining membrane consists of connective tissue containing about a dozen vesicles. The air may be released under water by puncturing the tube, and then takes the form of bubbles, whose volume is greater than that of the cavity of the tube itself.

The preparing organ, which Professor de Rougemont prefers to call "condenser," opens into the reservoir or preserving organ. Some of the vapour produced by the detonation was obtained by placing forty specimens in alcohol, weakened by the addition of one-third of water; soon after, single detonations occurred and vapour was sent up; in five minutes from immersion a rapid fire of explosions took place, and then the movement slackening they became less frequent, concluding with a volume of bubbles after death, probably owing to the relaxation at that moment of the sphincter muscle of the reservoir. Analyses made by Professor Billiter show the composition of the vapour to be:—oxygen, 73·1; carbonic acid, 20·6; nitrogen, 6·3. This large proportion of oxygen is sufficient to rekindle a smouldering match.

The preserving organs or reservoirs, lying behind the condensers, have a brown chitinous colour, and enclose a brown liquid containing minute, flat, brownish, hexagonal crystals; it has not been found possible to analyze it, but it would appear by analogy with similar substances found in *Carabus niger* and *auratus*, to consist of butyric acid. Its origin is doubtful, and it plays no part in the production of the explosion, but gives out a strong odour when expelled by that process; it produces a brown patch on glass, under which the explosion

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* MT. Schweiz. Entom. Ges., vi. (1881) pp. 99–105.

has been allowed to take place. How the compressed gas or vapour is produced does not appear.

Glands connected with the Bee's Tongue.*—In going over Mr. J. D. Hyatt's work on the structure of the tongue of the honey-bee,† Mr. J. Spaulding found in the mentum a small spiral tube, and following up the clue thus given, he discovered that it led to a glandular structure which he believes has not hitherto been described.

The process of dissection is to run the scalpel from the base of one mandible back across close to the neck and forward to the other mandible, turning forward and pinning: remove the brain and salivary glands; cut the œsophagus, as far forward as possible, turn it back, and there will be seen coming from the thorax the spiral ducts of two glands, which will be found lying one on each side of the œsophagus, in the space between the muscles of the wings. These consist of a dense mass of coiled and twisted glands. At the base the duct enlarges into quite a reservoir. The ducts unite within the neck, or just as they enter the head, and following the floor of the latter are joined by a pair coming in right and left. Following up one of these side glands, it is found to divide into three main branches, ultimately terminating in glands. The glands from the thorax bear a striking resemblance to the Malphigian tubules of insects, whilst those from the head are larger, different in shape, and composed of much smaller cells. Keeping to the floor of the head, the main duct passes on to the sub-mentum. Here, on joining the spiral tube coming from the lingula, it passes by an opening, common to both, into the mouth. Below the opening, the spiral tube dips into the mentum, and is imbedded in its muscles. At a point a little lower down it seems to terminate, judging from a side view, but a series of cross-sections shows it to gradually widen from this point to near the base of the ligula, where it terminates in a chamber that leads above into the sac and below by a valvular opening into the groove in the rod. This trumpet-shaped part is collapsed, the upper half of the tube being pressed down into the lower.

The author considers that it may be concluded from the size, position, and outlet of the glands, connected as they are with an inlet for the nectar of flowers, that they are organs that furnish the animal secretion that changes nectar into honey, and suggests that they may be the spinning glands of the larvæ modified, in which case they should be found either in an active or aborted condition in nearly all Hymenoptera. In conveying the nectar from the flower to its mouth, the bee probably uses the rod and sac as a suction- and force-pump; at least the author considers "it should, and if it does not, it is pure stupidity on its part. If some one demonstrates that I am all wrong now, evolution at no distant day will set me right, for there will be born a bee, less conservative, that will dare defy old usages and take

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* Amer. Natural., xv. (1881) pp. 113–9 (5 figs.).

† Amer. Quart. Micr. Journ., i. (1879).

a new departure: that bee, trust me, will make use of this cunningly devised apparatus, and produce honey cheaper than any competitor excepting the glucose man, and I hope and trust may worry even him."

Alternation of Generation in the Cynipidæ.*—In a paper of nearly 100 pages Dr. Adler deals with this subject, to which he was led by the discovery that from the eggs of *Neuroterus* there is developed an altogether different generation which has been hitherto regarded as belonging to another genus (*Spathegaster*); the species studied belong to four groups, *Neuroterus*, *Aphilothrix*, *Dryophanta*, and *Biorhiza*. Twenty-three species have their life-history described, of which four, all species of the genus *Aphilothrix*, exhibit no alternation of generation; all belong to the North German fauna.

In the third chapter the author deals with the formation of the galls, and devotes the fourth to an account of the organs of the insect which are adapted for the purpose of causing them. The process of oviposition appears to consist of three stages; in the first, the canal is formed by the spine at first passing under the covering scales at the base of the bud, and then turning into the centre of its axis; the egg, being seized between the setæ of the spine, is passed below this; when the tip of the spine is removed from the canal, the ovarian body enters into it, and is pushed forward by the spine until it reaches to the end of the canal; the ovarian stalk which occupies the canal is believed to have a respiratory function.

The reproductive organs in the two generations are reported to be very similar in character; the ovaries have the same structure, and contain from six to twelve eggs; as a rule, the agamic generations have a larger number of eggs than the sexual; the muscular vagina and its appended glands are alike in the two generations; on either side there is a simple glandular tube, the secretion of which probably serves as a fluid for the conveyance of the spermatozoa, and these glands are, in consequence, better developed in the sexual than in the agamic forms. It is curious to observe that there is a receptaculum seminis in the asexual generations, although, of course, it is to some extent rudimentary.

The period of the development of the larva varies in the two generations; being much shorter in the summer than in the winter one.

(1) The larva may be developed in the same year, and become completely developed, remaining for a year or more in the gall (*Aphilotrix*).

(2) In the first year the larva only attains to a certain grade of development, in which it passes through the winter, and is only fully developed in the second year; or

(3) The larva may remain for a long time in a very early stage, and only become more fully developed when the gall falls away (*Neuroterus*).

Dr. Adler believes that the present agamic form was identical with

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* Zeitschr. f. wiss. Zool., xxxv. (1881) pp. 151–247 (3 pls.).

the primitive one, or very nearly so; and he thinks that the alternation of generation is due to the steady though gradual alteration in climate, while adaptations to new conditions of life have more or less altered the whole organization of each species.

Shining Slave-makers (Polyergus lucidus).* — The Rev. H. M'Cook records the discovery at the foot of the Alleghany Mountains, near Altoona, of a nest of *Polyergus lucidus*, the American representative of the Legionary Ant of Huber (*P. rufescens*), an ant associated with that author's discovery of ant-nests, in which certain ants have associated with them, in a sort of slavery, ants of another species.

The nest had four gates separated a few inches from each other; the chambers were placed one above the other, united by tubular galleries. In an inner ovoid chamber numbers of the ants, male and female, appeared; mingled with these in large numbers were workers in three forms — major, minor, and dwarf of *Formica Schauffussi*. A portion of the excavated nest was broken into, and on the next day but one was visited. None of the shining ants were at work, but the "slaves" were very busy cleaning out the galleries; a portion of the slaves were engaged in an extensive migration; a few were carrying their fellows, but for the most part the deportation was confined to the males and females of the shining ants. It was wonderful to see the large virgin-queens carried up the perpendicular face of the cutting for eighteen or twenty inches, and then for the distance of six feet over the ground and through the grass, and this in a few seconds over a minute. The shining ants are able to take a most wonderful grip. One of them had fallen under the displeasure of another, who held her firmly grasped by the middle thorax. Anxious to preserve the colony from unnecessary loss, Mr. M'Cook lifted the two out on the point of a quill toothpick, laid them on his hand, and thrust the fine point of the quill between the jaws of the aggressor, and so teased her that she released her fellow. The rescued ant instantly clasped the palm of his hand, threw her abdomen under her, and then, with back curved like that of an angry cat, sawed and tugged away at the skin until an abrasion was made. The other ant still clung fast by her mandibles only to the toothpick's point, her body stretched out into space, her limbs stretched outwards, except one hind leg, which was a little bent upward, and thus without any perceptible support except that which her jaws gave her upon the quill-point, she hung outstretched for several minutes. About a month after its discovery the nest was again visited; it was abundantly peopled; the winged forms of the shining ant were however gone.

Having succeeded in colonizing these ants, Mr. M'Cook was able to confirm in many particulars the statements of Huber, Forel, and others, but he never happened to see the slaves feeding their masters. He noticed that they seemed to like to move towards both warmth and light, but he does not seem to have settled the question whether they would not prefer the warmth without the light. They would

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* Proc. Acad. Nat. Sci. Phila., 1880, pp. 376–84 (1 pl.). See 'Nature,' xxiii. (1881) p. 543.

appear to be very clean in their ways and persons. Various experiments seemed to establish the fact that these slave-makers always keep a guard ready at once for any attack.

Chorda Supra-spinalis of the Lepidoptera and the Nervous System of Caterpillars.*—Herr J. T. Cattie commences by describing the ventral vessel and sympathetic nervous system of *Acherontia atropos*; he finds that in that insect there is no paired system connected with the azygos nerves, and that the vagus system consists only of the *nervus recurrens*. He finds that from the first to the last ventral ganglion the sympathetic nervous system of the median nerves forms a connected whole, and that it is in direct connection with the tracheæ of the wings; the small lateral sympathetic ganglia of the head innervate the tracheæ, but they have no connection with the antennary nerves. He describes *nervi laterales transversi* as connected with the thoracic ganglia, and two delicate nerve filaments as taking their places in the abdominal ganglia. He believes that the chorda of *Acherontia atropos* consists of gelatinous connective tissue, and that it has the function of a lymphoid organ.

Beaded Villi of Lepidoptera-scales.†—Dr. Royston-Pigott claims to have discovered, in carrying out the investigation of the molecular structure of insect scales with a power of 3000, that "the striated surfaces of these scales, though appearing approximately beaded, are really covered with villi, chenille or velvet pile, terminating in a spherule. The recognized object of these striæ, regarded as corrugations, is to give strength to a most delicate tissue, which are again supported by *cross striæ*. Upon these transverse striæ are villi erected upon them by twos and threes, and summits consisting of a refracting spherule." The object upon which these villi were first detected was the scale of *Vanessa Atalanta* or Red Admiral.

Histolysis of the Muscles of the Larva during the Postembryonic Development of the Diptera.‡—M. H. Viallanes has made more than 400 sections of the hardened larvæ and pupæ of *Musca vomitoria*. He finds in the larva that the primitive muscular fibre in transverse section presents a sarcolemma containing the central mass, in which may be made out Cohnheim's areas and nuclei. From the first day of pupal life these fibres begin to disappear in one of two ways, both of which may be seen in the same animal.

a. Disappearance of the muscle accompanied by proliferation of the nuclei.—The sarcolemma disappears even before the pupa has taken on its characteristic brown colour; the contractile substance becomes homogeneous, the lenticular nuclei acquire a spherical shape, and become complete cells, surrounded by a layer of protoplasm and an enveloping membrane. Four or five spherical granules appear in the protoplasm, and by growth become as large as the nucleus; on the disappearance of the membrane these bodies separate from the

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* Zeitschr. f. wiss. Zool., xxxv. (1881) pp. 304–21 (1 pl.).

† Proc. Roy. Soc., xxxi. (1881) pp. 505–6.

‡ Comptes Rendus, xcii. (1881) pp. 416–18.

nucleus; the contractile substance being thus absorbed, the embryonic cells increase in number, and the primitive fibre is seen to consist of a perfectly homogeneous substance, with a sinuous border, the depressions in which are occupied by the accumulated embryonic cells; the central part of the contractile mass is pierced with holes which are likewise filled with these cells; and, at a later stage, the place of the fibres is merely indicated by a mass of proliferating embryonic cells.

b. Disappearance of the muscle, accompanied by the degeneration and death of its nuclei.—After the disappearance of the sarcolemma, the centre of the still lenticular nuclei is seen to be occupied by fine granulations; these become more and more rare, till they disappear, when the nucleus is merely represented by its sheath; the contractile layer meantime has been disappearing, and that so slowly and so regularly that the general form of the fibre remains unaltered. The final product is a colourless and very finely granular substance, in which are found nuclei in various stages of degeneration.

Axis-cylinder and Peripheral Nerve-cells in relation to Sense Organs in Insects.*—The nature of the nervous swelling which occurs at the base of certain hairs in the Arthropoda, and of the filament which terminates this swelling, has been studied by J. Künckel and J. Gazagnaire in the *Diptera*.

The swelling in question is found to be of a uniform structure in all cases; it is connected by one extremity with one of the ultimate nervous fibres, and by the other with an ordinary or a specialized hair. The nerve-fibre from which it springs consists of a neurilemma containing nucleated cells and of an axis-cylinder; the nervous swelling has a capsule composed of the dilated neurilemmar sheath, and this expands at the base of the hair into a small cup whose edges are in union with the hypoderm surrounding the chitin of this part; into the capsule the axis-cylinder penetrates, and gradually widens out into a bipolar cell of some size, provided with a nucleus and refringent nucleolus, and finely granular like the axis-cylinder itself, but devoid of a cell-wall; the distal end becomes attenuated and ends in a small strongly refringent rod which fits into the centre of the hair and receives external impressions from it. The bipolar cell is enveloped in protoplasm which generally contains a variable number, not exceeding eight, of large nucleated cells; but all stages may be observed, from that in which the bipolar cell exists alone in its sheath, up to that in which it has its protoplasm and eight surrounding cells. These accessory cells appear to be of the same nature as some other cells which occur in certain dilatations of the neurilemma, which are especially abundant at points where the axis-cylinder gives off several branches; for they are similarly affected by reagents, and when but one occurs in the sheath of the ganglion, it is, like those in the neurilemmar diverticula, found pressed against the walls. Such is the essential structure of every nervous swelling in insects which is devoted to the transmission of

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* Comptes Rendus, xcii. (1881) pp. 471–3.

general or special sensations. As the most important element in these organs is a single cell, the authors purposely avoid applying to them such terms as "ganglion-cells," "ganglionic swellings," or "nerve-ganglia."

γ. Arachnida.

Sexual Organs of the Phalangidæ.*—Dr. H. Blanc has studied several points in the anatomy and physiology of these organs in four species of *Phalangium*. In forming conclusions upon disputed matters he has been careful to study the tissues in the fresh state, when possible, so as to eliminate the possible evils attending the use of reagents.

The *testis* shows its primitively paired condition by being made up of two lateral lobes connected by a strongly constricted bridge of tissue; an efferent duct issues from the apex of each of the two forwardly directed lobes, which become attenuated towards this point. The ducts unite and form on the sternum a knot in which the vas deferens originates, between the penial sheath and the accessory generative gland; their walls consist of an external pavement epithelium and an internal layer of cylindrical cells which probably supply a hyaline liquid to the sperm in its passage. Just before entering the penis the vas deferens acquires a stout chitinous lining and an external coat of obliquely concentric muscular fibres, and the epithelium becomes very thin; this layer almost disappears in the fine prolongation which enters the penis, but the chitin persists.

Near the apex of the *penis* are two oval chitinous disks, supporting an accessory gland, in *Phalangium opilio* and *cornutum;* in *P. longipes* and *rotundum* the gland is in immediate contact with the posterior section of the penis; *P. longipes* is also remarkable for having a sac-like diverticulum of the chitinous layer of the middle of the penis, forming a kind of sheath to that organ, and surrounding it as far back as the origin of the terminal gland; the sac is longitudinally divided into two smaller divisions by a fold of chitin; these divisions contain what is apparently an albuminous secretion, and they probably constitute an accessory generative gland. In all the species the posterior end of the penial chitinous sheath, which is single, bears a ridge or fold to which the protractor muscles are attached, and from which they pass to the sides of the body. The glands already mentioned as opening near the end of the penis also occur in the female, and are probably brought into use during copulation.

The testis is covered by a very delicate *tunica propria* consisting of pavement epithelium; but the muscular fibres which usually underlie this layer in the Arthropoda, appear to be absent, and it is consequently in direct contact with the internal epithelium; this epithelium consists of (1) the true epithelial cells, which are polygonal, with cell-wall, clear protoplasm and granular nucleus, united in groups of six to eight, and (2) of smaller cells intercalated between the former in groups of

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* Bull. Soc. Vaud. Sci. Nat., xvii. (1880) pp. 49–78 (3 pls.). Cf. this Journal, iii. (1880) pp. 248, 423.

two or three, the mother-cells; they are round, with granular protoplasm and nucleus; there is a small but strongly refringent nucleolus, and a very delicate cell-wall.

The *spermatozoa* are formed within the mother-cell by dichotomous division of the nucleus, resulting in the production of eight to twelve nuclei; when these are formed the protoplasm itself divides and becomes aggregated around the different nuclei, which continue to divide until from twenty to thirty daughter-cells are formed; their nuclei have all the characters of the original nucleus of the mother-cell; each occupies nearly the whole of its cell; the mother-cell now has a distinct doubly-contoured wall consisting of the old cell-wall strengthened by the adhesion to it of the peripheral layer of protoplasm, and is consequently a cuticular or non-cellular structure in this case, whatever it may be in Insects. The nuclei now undergo great changes; their granules decrease in number, increase in size, and then unite to form a single mass, which then elongates and assumes a horseshoe shape; the horseshoe breaks up into four, six, and finally eight parts which adhere to the nuclear membrane; the latter and its liquid contents are now absorbed and each portion of the altered nucleus becomes directly surrounded by the protoplasm of the daughter-cell, and constitutes thereby a cell of the tertiary order. These latter cells escape into the mother-cell at the sexual period, by rupture of the walls of the daughter-cells, forming the spermatozoa which finally reach the vas deferens by rupture of the capsule of the mother-cell. The mature spermatozoa are biconvex lenticular bodies, ·003 mm. in diameter, rendered most convex in the centre by their nucleus; they exhibit no true independent movements, but are impelled by simple *vis a tergo* as far as the muscular bulb of the vas deferens, which then contracts and sends them to the end of the penis into the terminal gland, and into the receptacula seminis. The nuclei of some of the mother- or daughter-cells are liable to suffer a degeneration, by which the granules, and even in some cases the cell-protoplasm itself, become replaced by a number of small bodies, and in this condition refract brilliantly; such cells are also observed in some Crustacea; they appear to be neither calcareous nor fatty in composition.

In the *female organs* Dr. Blanc finds a pair of receptacula seminis, which vary in form, opening into the vagina; their function is decided by the spermatozoa which they have been found at certain times to contain. The ovum, which has a delicate vitelline membrane, increases immensely in size while in the oviduct, distending this tube; a pressure is thus applied to the adjacent receptacula seminis and sperm is extruded; the writer assumes the occurrence of amœboid movements of the spermatozoa, to account for the penetration by them of the vitelline membrane. With regard to the question of hermaphroditism, it is placed beyond doubt that ova often do occur, chiefly in young individuals, on the surface of the testes, manifesting the same pedunculate mode of attachment and the same structural characters as in the ovary itself. It is only male individuals which exhibit the phenomena of hermaphroditism; and these phenomena take the form of rudimentary hermaphroditism; that is to say, the structural arrangements do not permit self-fertilization.

Auditory Organ of the Ixodidæ.[*]—Dr. G. Haller points out that near the hinder margin of the terminal joint of the first pair of feet of these animals there are two foramina, which are covered by a colourless transparent membrane; within this we find chitinous hairs and otoliths, which present an extraordinary resemblance to the auditory arrangements of the Crustacea. The *Ixodes* of the dog afforded the author an ample supply of material.

δ. Crustacea.

Deep-sea Crustacea of the Gulf of Mexico.[†]—M. Alphonse Milne-Edwards has a note on the forms, the names of which were given in this Journal, *ante*, p. 240. Not only is the number of species much greater than was expected, 53 out of 240 being new in the groups already examined, but 40 are new *generic* types. Certain groups which had been supposed to be absent from the American seas are very richly represented at these great depths; *Galacantha* has its carapace armed above and laterally by large sabre-shaped spines; and *Orophorhynchus* can withdraw its eyes under its rostrum.

Crabs proper—Brachyurous Decapods—disappear below 500 m. from the surface; at 800 m., however, there was found *Bathyplax*, which takes the place of *Gonoplax* of the French coasts, but it is blind. Representatives of *Willemoesia* were found at 3500 m., and these too were blind.

The infinite variety of the forms is, however, the most astonishing point, and great difficulties are raised as to future classifications; transitional types abound, and groups hitherto regarded as very distinct are now linked by intermediate forms. As examples, the author cites the Paguridæ, generally placed among the Anomura, and which have as yet had no link uniting them to the Macrura; now there is *Pylocheles Agassizii*, in which the abdomen is not soft and asymmetrical, but is formed of solid regular rings, and terminated by swimmerets. This creature lives in holes, which it closes by means of its claws. *Mixtopagurus* has the abdomen more developed on the right than on the left side, and divided into seven somites, of which the last two are alone large and hard. *Catapagurus* has a very small abdomen and leads to *Spiropagurus*.

There are some curious adaptive modifications: *Eupagurus discoidalis*, which lives in the tubular shells of *Dentalium*, has one of its claws spherical. *Xylopagurus* lives in holes in wood, and has its abdomen converted into an operculum for covering one of the two holes of its retreat.

Similar connections are found between the Dromiadæ and the Homolidæ; and on the whole the author concludes that submarine explorations will aid palæontological investigations in gradually

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[*] Zool. Anzeig., iv. (1881) pp. 165–7.

[†] Comptes Rendus, xcii. (1881) pp. 384–8.

filling up the lacunæ which are now seen in zoological systems, and he announces a French exploration of the Mediterranean.

Studies on the Crustacea Decapoda.*—J. E. V. Boas has been investigating the integumentary skeleton of these forms. Starting with the Penæidæ, he finds that on the one side there are connected with them all the other "*Salicoques*" which form a natural and allied, though very distinct group, for which he proposes the name of Eukyphotes. On the other side we find, as descendants of the Penæidæ, the Macrura + Anomala and the Brachyura, which unite to form a large and rich natural division. Of the extant forms, *Homarus* (and *Nephrops*) stand the nearest; from this group, well represented in the past, we have the genus *Polycheles* and the Loricata, and also the Thalassinidæ descended. *Astacus* is intermediate between these last and *Homarus;* they too appear to have given rise to the Anomala, which fall under three heads—Galathæidæ, Hippidæ, and Paguridæ. *Porcellana* is a modified Gallathid, and *Lithodes* a modified Pagurid. The Brachyura appear to have arisen from one of the Anomala, to which the Dromiaceæ stand nearest.

These views are displayed in a phylogenetic table, and in the following tabular classification, which it is worth while to reproduce, as by dropping altogether the division of the Decapoda into Brachyura and Macrura—a division as valuable, the author thinks, as one which would group Mammals as Rodents or Non-rodents—it probably marks a considerable step forwards.

SUBORDO I. NATANTIA.

1. Penæidæ.
2. Eukyphotæ.

SUBORDO II. REPTANTIA.

3. Homaridæ (+ Astacus).
4. Eugonidæ.
5. Loricata.
6. Thalassinidæ.
7. Anomala.
    a. Hippidæ.
    b. Paguroidea.
    c. Galathæidæ.
8. Brachyura.
    a. Dromiaceæ.
    b. Brachyura genuina.

The author has discovered that the forms known as *Cerataspis longiremis* and *C. monstruosus* are Penæids in the *Mysis*-stage, but they belong to forms the adults of which do not seem to be yet known; they have no relation, as Dohrn thinks, to the Schizopoda. Abundant as the Penæidæ were in the Jurassic and other epochs, their forms did not differ much from those now living.

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* Skrift. K. Dansk. Vidensk. Selsk., i. (1880) pp. 25–210 (7 pls.).

The author deals in detail with the characters of the appendages of the group just mentioned, as also with those that follow. Into these elaborate accounts it is impossible to follow him here, and only the more important general points can be dealt with.

The Jurassic genera *Udora* and *Udorella* are seen to belong to the Eukyphotes by having the epimera of the second abdominal covering those of the first abdominal somite; to this group also belongs *Hefriga*.

Distinct as are the Loricata, they would appear to be not distantly related to *Homarus;* the possession by them of an internal appendage on the abdominal feet of the adult female is, indeed, a point of difference, but, as this character is found in the Thysanopoda though not in the Penæidæ, and in the Eukyphotes though not in Homarus, as well as in such Decapods as *Axius*, the author is of opinion that it is an ancestral character, which reappears by way of atavism. The young of this group are transparent, and would seem to be surface-swimmers. The lateral parts of the carapace are, as in *Phyllosoma*, separated from the dorsal by a crest; but this crest is low. *Archæocarabus Bowerbanki* would appear to be a true *Palinurus; Cancrinus* to be intermediate between the Palinuridæ and the Syllaridæ; its curious multiarticulate flagellum to the external antennæ is a specially transitional arrangement. The ancestral form of the group seems to be represented by the *Palinurellus* lately described by Von Martens.

The Thalassinidæ, if *Axius* may be taken as their type, certainly pass through a natant-stage; the young, altogether similar in most points to the adult, having small functionless epipodites to their thoracic appendages, and the abdominal appendages larger than in the adult.

Mr. Boas is unable to accept the division of the Anomala suggested by Professor Claus, who, it will be remembered, proposed to place the Paguridæ and Galathæidæ with the Macrura, and the Hippidæ and Porcellanidæ with the Brachyura. The Danish naturalist points out and insists on the relations between *Galathea* and *Porcellana;* indeed, all the forms he includes under the Anomala have important characters in common: the thoracic limbs, maxillipeds, maxillæ and mandibles, no less than their developmental history, unite them most closely; "if there exists a natural group, it is that of the Anomala." They have many points of affinity with *Axius*, although not directly derived from it.

The Brachyurous Dromiaceæ have numerous points of affinity to the Anomala, but their ancestor must have been more closely allied to *Axius*.

When we make a general survey of the results obtained by the author, we find that from semi-transparent forms, delicate, and actively swimming (Natantia), we pass to forms with a thick test, ill-adapted for swimming, but able, thanks to their powerful abdomen, to make leaps of considerable length (Homaridæ). Thence we are led to the most highly differentiated Decapods, the Brachyura, in which, hand in hand with the reduction of the abdomen, there has been a marked increase in the development of the thoracic appendages; creatures well adapted for walking are now seen. The "fundamental trait" in the phylogenetic development of this group presents a very striking analogy to what is seen in the Vertebrata.

The side branches are no less interesting; singular as is *Pagurus*, with its soft tail enclosed in a shell, *Lithodes* and *Birgus* are still more specialized. In the Penæidæ the buccal and ambulatory appendages are closely connected; the second and third maxillipedes do not differ from these latter. In the Brachyura there has been centralization and specialization; the mouth-organs differ much from the ambulatory limbs, the first of which are specially modified to form an organ of prehension. "The superior forms are, then, when compared to the inferior, centralized, and their different parts are specialized."

These studies of M. Boas will doubtless have an important influence on carcinology; no abstract can give an idea of the elaborate and detailed accounts which he gives of the forms which he has examined, and many of which he has figured. There are altogether 216 figures. Latin diagnoses of the groups and genera are given, and the whole is almost more than summed up in the French *résumé* with which the essay concludes.

Change of Colour in Crabs and Prawns.* — Dr. Fritz Müller contributes some instances of this phenomenon—already discovered by H. Kröyer—from the Brazilian fauna.

The shrimp *Atyoida potimirim*, of the sub-family *Atyinæ*, has a female which when adult and living among water-plants is usually dark green, sometimes inclined to blue or brown, occasionally of a pure blue with a pale brown streak down the back; when put into a glass vessel it fades to an increasingly pale brown, which disappears and leaves the animal colourless and transparent in the course of a few days; a dark brown specimen placed with a number of others which had the usual greenish hue assumed their colour in a few minutes. A black *Palæmon* taken from deep water became first dark, then pale blue, and the colour, losing its even distribution, became accumulated in many closely-packed patches; after half a day from the time of capture it had lost all colour, with the exception of the caudal swimmeret, which remained blue. The male of a small land-crab, *Gelasimus*, whose carapace is marked with pure white and light green, loses these colours when captured, and they are replaced by a uniform grey. The variations in colour of the swimming crab *Nautilograpsus* are due to temporary changes of colour according to circumstances, and are not rightly explained by Moritz Wagner as being permanent, and as leading the individuals to frequent those beds of seaweed which harmonize with their particular colour, a conclusion which is further opposed by the record given in the 'Challenger' report of the different surroundings in which the same crab may occur, a fact which implies a change of colour. This and similar instances of variation are better explained by the view of *segregation*, than by that of the *migration* of the differing forms.

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* Kosmos, viii. (1881) pp. 472-3.

Circulating Apparatus of Edriophthalmous Crustacea.*—In the *Amphipoda* the heart traverses the five anterior thoracic segments and part of the sixth, and has three pairs of cardio-pericardiac orifices. The anterior and posterior aortæ in which it ends have each a pair of valves at their origin; they lead into a large ventral sinus; for the one, the inferior aorta, this is the sole destination of its blood, but the superior aorta supplies the antennæ, brain, &c., ending in the labrum, and dispersing its blood in the cephalic lacunæ, whence it reaches the ventral sinus. A pericerebral ring is formed by the union of two of the cephalic branches, one of which passes through, and the other over the œsophageal nerve-collar or brain, an arrangement which is absolutely confined to the *Amphipoda* and *Læmodipoda*; further, a vascular collar surrounding the œsophagus is formed by the labral trunk, like that of Isopoda. The heart itself gives off from the sides of the superior aorta in *Talitrus* two facial vessels, which supply the muscles of the mouth-organs. The ventral sinus lies, along the anterior aspect, between the integument and the alimentary canal; it supplies a pair of short vessels to each segment, each vessel dividing to give a branch to each of the appendages of the segment; the rudimentary parts, viz. the lamina of the incubating chamber, and the epimera of the non-branchiated segments, are similarly supplied; the blood returns from the segment to the pericardium by vessels which anastomose and give rise to pericardiac vessels. The pericardium lies in the dorsal region of the thorax and abdomen. These details do not refer to the *Hyperina*, but specially to the leaping *Crevettina;* the walking *Crevettina* differ from the latter, among other points, in the possession of but a single pair of cardio-pericardiac openings.

The *Caprellidæ* agree precisely with the *Amphipoda*, except in the absence of the circum-œsophageal vascular ring and in the points necessarily connected with atrophy of the abdomen; they are most nearly related to the *Corophiinæ* by the characters of their vascular system.

Amphipoda of the Adriatic. —Herr Olman Nebeski has a series of notes on some of the organs of these forms, and concludes with a list of the species he has observed.

In dealing with the *unicellular glands*, he describes those found in the legs of the Corophiidæ; on the two pairs of thoracic appendages succeeding the gnathopods he finds an internal cavity, but feebly provided with muscles and containing a large number of glandular elements, each of which represents one cell, and has a special cuticular efferent duct; they are found from the second to the third joint, and the ducts may or may not unite, but they all pass to the dactylus. Although similar in histological structure, the cells appear to differ in chemical constitution, for some are more rapidly tinged by Beale's carmine or picrocarmine than others, which are more rapidly and deeply tinged by osmic acid; they may be distinguished as

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* Comptes Rendus, xcii. (1880) pp. 216–18.
† Claus' Arbeiten, iii. (1880) pp. 111–63 (4 pls.).

the "dark" and "clear" cells. The former are only found in the basipodite, and their form varies in different species; the pale cells may be found in any of the joints, and in the upper ones their duct always remains distinct. The details of various genera are entered into, and the "thread-like web" in the Corophiidæ, the origin of which Mr. Spence Bate was unable to determine, is shown to be a product of these gland-cells.

The unicellular glands of *Orchestia* are formed on another type, the intracellular cuticular tubules have a relatively wider lumen, and are correspondingly less numerous; the glandular apparatus is, further, not so centralized, for they are found over the whole of the body, and their duct may open on the body-wall by a proper pore. Those on the appendages are more especially described, and it is pointed out that they are similar in character in the two sexes; *Orchestia*, it is to be noted, is more terrestrial in habit than its allies, and it is possible that the secretion of the glands protects the gills from drying too rapidly.

The penal glands of the *Crevettinidæ* are appended to the hinder region of the enteron, where they form a paired arrangement, consisting of two tubes, which are diverticula of the tract; differing as they do in details in the different genera, they would appear to occupy constantly the same position, just in front of the commencement of the rectum; being outgrowths of the end of the mid-gut, they cannot be regarded as the homologues of the Malpighian vessels of insects. When least modified, as in *Melita*, they are unpaired. After describing the differences seen in various genera, the author states that the amount of concretion which may be collected in them is very great in *Orchestia*, whereas in the rest there are no solid excretory products.

The rectum of *Orchestia* presents some peculiarities; it extends throughout the whole length of the abdomen, and is divisible into two portions, the hinder of which corresponds to the rectum of its allies. In the front portion the epithelial layer is higher in its dorso-median portion; at the sides of this ridge there are two epithelial folds, while an unpaired fold arises from the ventral surface; the whole is lined by a thick cuticle, marked by longitudinal ridges, each of which is beset with a row of fine cuticular setæ, which appear to aid in the removal of the fæces. The investing musculature is divided into two lateral parts, and the fibres do not run longitudinally, but obliquely, so as when contracting to act both as circular and as longitudinal muscles. The hinder portion of the rectum does not essentially differ from that of the other *Crevettinidæ*, except in the great development of its epithelium. This elaborate arrangement is probably to be associated with some unknown peculiarity in the feeding of *Orchestia.*

The gills of *Orchestia* also present some peculiarities; they form small, relatively thick and strong plates, which are attached from the second to the sixth pair of thoracic legs; the two lamellæ of the hypodermis are widely separated, and contain a far larger cavity than is to be found in *Gammarus;* they consist largely of broad cylindrical cells, with rounded large nuclei; in parts the matrix is considerably modified and forms delicate and very high hypodermal cells, which, gradually diminishing in width, project far into the interior of the gill, unite with those of the opposite side and form a palisade-work support.

In *Orchestia*, further, ova appear to be developed in the "testes"; the male organs generally resemble those of *Gammarus*, and form simple tubes, consisting of a germ-gland and an efferent portion. The terminal piece opens at the seventh segment into two short chitinous tubules, which are the copulatory organs. There is a pretty large terminal vesicle. Only the hinder half of the tubes produce male products, the anterior quite constantly developing eggs, but for these there is no special duct. The spermatogenous portion is lined by cylinder epithelium, and appears of considerable width; the large cells with coarsely granular plasma secrete an investment constituting the spermatophores; in the median division of the cavity is the germinal portion, consisting of a continuous plasmatic mass, in which are imbedded spindle-shaped nuclei; the plasma is finely granular, and becomes aggregated around the nuclei to form well-marked cells, the spermatoblasts. These undergo some changes before they pass out to give rise to spermatozoa; the nucleus grows to a great size, as does also the nucleolus.

The ovigerous portion has much the same histological structure; the spindle-shaped nuclei form cells, which differ in no respect from the spermatoblasts, and they only are distinguished by developing into ova; as Nebeski justly points out, this resemblance affords a new proof of the homology of the egg-cell and the spermatoblast. After the growth of the nucleus, the plasma begins to deposit yolk-material, the egg increases in size, and gets a vitelline membrane. The eggs developed in the male differ from those of the female in the structure of their protoplasm, for the yolk-spheres are not in them so distinctly developed, and it would appear that they never become fully matured. This remarkable phenomenon has not, therefore, any physiological significance, and in structure the organ is truly a testis. The author reminds us that *Phalangium* stands in a similar condition.

In the sixth and last portion the author deals with the Crevettine fauna of the Gulf of Trieste; he describes as new *Probolium tergestinum*, and *Dexamine dolichonyx*, and has notes on the rarer or more difficult species.

New Species of Entomostraca.*—Mr. V. T. Chambers records these from the United States.

Tachidius (?) *fonticola* n. sp. is pale yellow, with the eye-spot very large and bright crimson. The antennæ of the female are short, thick, and simple; those of the male are 6-jointed; the setæ of the legs of the female are much shorter than those of the male. Length of body, 0·385 mm.; of terminal setæ, 0·3 mm.

So far as is known, this species does not inhabit a portion of the earth's surface more than two yards square. At the famous locality known as Big Bone Springs, large "gums" (hollow trunks of trees)

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* Journ. Cincinn. Soc. Nat. Hist., iv. (1881) pp. 47-8 (2 pls.).

are sunk in the ground, and the water of the springs rises up, and running over the top spreads out over the ground, or runs off in small streams. At one of these springs, which is near the edge of a bank of Big Bone Creek, the water spreads over the ground toward the bank over which it trickles. There is not enough of it to form a stream, spread out thus and quickly absorbed in the ground as it is, but it affords a fine place for the growth of a species of *Oscillatoria*, which forms a tolerably thick mat upon the surface, and in which *T. fonticola* lives in countless multitudes. All the species of *Tachidius* hitherto known live in the sea, or in brackish water connected with it. How the creature found its way to its present habitat is, the author considers, a mystery, but the water of all the springs is strongly impregnated with common salt, iron, sulphur, and other mineral ingredients in less quantity. Moreover, the animals were never found in the "gums" themselves, but only in the puddles outside, which being warmed by the sun were, through evaporation, more strongly saline.

Diaptomus (?) *kentuckyensis* n. sp. is white and transparent. The abdomen of the male has five, that of the female only four segments. Cephalothorax with five distinct segments, but when crushed under pressure the head appears to divide into four segments. Length from apex of head to end of terminal setæ, 1·5 mm. Antennæ as long as the body. The difference in the male and female abdomen suggests a doubt whether it properly belongs to *Diaptomus.*

Adriatic Crustaceans Parasitic on Fish.*—A. Valle enumerates 69 species belonging to the Entomostraca alone. He gives the synonyms, and states on what species of fish each is found. The abundance of these parasites may be inferred from the fact that in 250 out of 670 specimens of fish examined by the author himself, crustacean parasites were found, representing 66 species; i. e. 38 per cent. of all the fish were affected. A new species of *Brachiella*, *B. oblonga*, is mentioned as occurring below the pectoral fins of *Mugil cephalus* and *M. saliens*, and a new *Philichthys*, *P. Richiardi*, has been once found in a canal of the præopercular bone of *Box salpa.*

Vermes.

Development of Hermella alveolata.†—Dr. R. Horst describes the ova of this Annelid as having a highly granular vitellus and large germinal spot; on the entrance of the spermatozoa the vitellus shrinks away from the investing membrane, and, owing to the concentration of the granules of the deutoplasm, there is developed a transparent peripheral layer. As the spermatozoa penetrate the vitelline membrane, a filament larger than the rest, and similar to the pseudopodium of an amœba, advances from the yolk to meet a spermatozoon. After about twenty minutes the two become fused, and the vitelline process contracting carries the fertilizing element into the yolk. About an hour later the yolk becomes flattened at one pole, at which the "polar globules" soon appear; the egg then commences to divide.

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* Boll Soc. Adriat. Sci. Nat., vi. (1880) pp. 55–81.

† Bull. Sci. Dép. du Nord, iv. (1881) pp. 1–4.

Contrary to the opinion of Quatrefages, the author believes that the first cleavage-groove always has a relation to the position of the globules in question, and that it does not appear at an indefinite point. An *amphiblastula* is formed. Twelve hours after fecundation the embryo has the form of a mesotrochal larva, with a group of long cilia at the cephalic pole. After four days the larva is cupola-shaped, owing to the great development of the pre-oral portion; the œsophagus is lined by vibratile cilia, and the anus is terminal; there is a groove on the ventral surface, four temporary setæ on either side, and two small brown eye-spots.

Anatomy of Sternaspis scutata.*—M. Max Rietsch describes some points in the structure of this Gephyrean.

After a general description of the external characters, he shows that the integumentary layer consists of a thick and resistent fibrous portion, striated parallel to the surface, and invested by a layer of setæ which alone appear to represent the epidermis, and lined internally by a granular layer, in which nuclei can sometimes be detected; from this there are given off a number of filaments, which pass into the setæ and appear to represent the terminations of nerves.

The muscles which cause the invagination of the anterior portion of the body are highly developed; the digestive tract forms a number of folds, and coils spirally around the generative organs; there is a wide, short, and protractile pharynx, with glandular projections, a narrower and longer œsophagus, analogous in its structure to the stomach, but distinguished from it by the absence of a vibratile canal and by the non-granular character of its epithelial layer; the stomach is the largest portion of the intestine, and its glandular epithelium is highly developed and gives rise to a number of internally projecting, longitudinal elevations; the secretion appears to be biliary in character. The nervous system is composed of two cerebral ganglia, a wide collar, and a ventral cord which is enlarged at one point owing to the great development of its connective tissue. The branchial filaments have no cilia, and their internal cavity is divided longitudinally by a fibro-muscular partition; the two sinuses thus formed communicate at either extremity; the blood, being coloured red, is easily seen in its passage through them. An account of the other organs is reserved.

Entozoic Vermes.†—Dr. R. Moniez mentions but does not describe a large *Spiroptera* which he found under the mucous membrane of the stomach of the rabbit, and for which he proposes the name of *S. leporum.* In the mole the same author has found *Tænia Barroisii* n. sp., which is distinguished from *T. bacillaris* by its greater size and thickness, while the rings are shorter, and the ova without appendages and smaller than in the form just named.

Dr. Moniez also points out that in *Abothrium gadi* the vessels contain a spiral tube, which is distinct from their walls and can be unrolled like a trachea.

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* Comptes Rendus, xcii. (1881) pp. 926–9.

† Bull. Sci. Dép. du Nord, iii. (1880) pp. 447–8.

Structure of the Cestoda, and especially of Tetrabothriidæ and Tetrarhynchidæ.*—Herr Theodor Pintner comes to the following conclusions with regard to the water-vascular system:—It consists of numerous ciliated infundibular cells, which are found in the whole of the body, but are chiefly collected into a zone which lies between the epithelium and the parenchyma, and which are provided with very long capillary efferent ducts; each of them is to be considered as a unicellular gland. The substances collected into these funnels are carried into a system of vessels which extends throughout the whole length of the body, and which opens into a terminal contractile vesicle; the matrix of the walls of these vessels is a well-developed epithelium containing a number of yellowish drops, insoluble in alcohol. The type from which these longitudinal vessels may be derived is presented by a simple loop, formed of a dorsal and a ventral branch, which extends to the anterior margin of the head, and, by its tendency to form anastomoses, gives rise in various species to a series of complicated arrangements. In all the Tæniadæ, Tetrabothriidæ, and Tetrarhynchidæ there are on each side of the body two longitudinal trunks, while in the Bothriocephalidæ, Caryophillidea, and Ligulida these four trunks break up into from ten to twenty-four longitudinal trunks, which are connected with one another by transverse anastomoses. In an early stage the four vessels are of much the same size, and all open into the terminal vesicle; later on, the two ventral enlarge at the expense of the two dorsal vessels; so that in all the free joints, or in very long chains, the latter appear to be atrophied. In addition to their communication with the exterior by means of the terminal vesicle, the vessels open at the hinder margins of the joints; in *Triænophorus nodulosus* alone there are special orifices on the head and neck. Cæcal or ramifying processes are never developed on the vessels, and they have no communications with the lacunæ in the tissue of the body.

The author would agree with Hatschek in ascribing the closed condition of the ciliated infundibula in the Platyhelminthes to the absence in them of any body-cavity.

In describing the structure of the head in *Tetrarhynchus longicollis*, the author points out that the two sucking-disks on it are really formed by the fusion of two on either side. The remarkable flattening of the head in this species makes its "orientation" a somewhat difficult matter; consideration, however, of the facts that the water-vessels and nerve-branches are found to the right and left of it, and not on the ventral or dorsal surface, leads the author to think that the plane of flattening is perpendicular to the plane along which it ordinarily takes place in Cestodes; while the head is not bilaterally symmetrical, but bi-radial, although the proof of this is obscured by the difference in the size of the branches of the two water-vessels.

After describing in detail the structure and musculature of the proboscis, Herr Pintner comes to histological characters; it is not in *Tetrarhynchus* only, but in all Cestodes that he has failed, notwith-

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* Claus' Arbeiten, iii. (1880) pp. 163–242 (5 pls.).

standing the greatest care, in detecting the pore-canals in the cuticle, the presence of which has been so frequently asserted; instead of ducts he would speak rather of small hairs as investing the cuticle, but he finds no sign of any ciliation. Below the "hairs" he finds a thicker cuticle, then a delicate layer with transverse fibrillæ, and another below that with longitudinal fibrils; and all these he believes are, with rare exceptions, to be found in all the Cestoda.

Under these, in *Tetrarhynchus*, there is in the head a special layer made up of bundles of fine non-nucleated muscular fibrillæ, which give a diagonal-square pattern, even on the most superficial examination. Below this is an epithelial layer, in which there are some indications of unicellular glands, and under this, and separating it from the proper parenchyma of the body, there is a cellular layer of a remarkable character; consisting, as it does, of irregular membraneless cells of various sizes, and containing a homogeneous dirty plasma, which gives off processes in all directions, which unite with those of the neighbouring cells and form a tubular network investing the whole body-parenchyma. These cells, which can only be rendered distinct by treatment with osmic acid, have well-marked nuclei and excentric nucleoli. The connected cells give rise to smaller or larger canaliculi which communicate with one another and run in various directions.

This system would seem to have the following functions: some of the cells further assimilate the nutriment taken in by the integument, and pass it to the canaliculi of the plasmatic canal system, other cells take up the innutritious material and convey it to the ciliated infundibular cells of the excretory system, to be evacuated.

As to the parenchyma, the author is largely in agreement with V. Kennel's results on *Malacobdella;* in the most anterior part of the head he finds a special compact tissue, consisting of a larger central and of four smaller lateral portions; pale red in colour and containing doubly-contoured fibrillæ which call to mind elastic connective-tissue fibres or the supporting fibres of the gelatinous tissue of the Medusæ, it has in its most central portion very pale cells with processes, which resemble the mucous or gelatinous tissue of the higher animals.

The muscular tissue is either transversely striated and without nuclei; or smooth and without nuclei; or smooth with a nucleus in the sheath; or smooth, with nuclei; or branched and flattened. As to the nervous system, he finds that it consists of a flattened mass of ganglion-cells which ends in a point posteriorly and is enclosed in a membranous sheath, provided with nucleated muscular fibres. Two nerve-trunks are found dorsally and ventrally to this cerebral mass, which is placed between the sucking-disks. At the level of the brain these dorsal and ventral trunks are connected by a transverse commissure; the trunks on either side unite, to be again separated further down, and thus there is formed a nerve ring which surrounds the cerebral mass. The two outer nerve-cords pass between the water-vessels into the outer parenchyma, and give off at regular distances transverse branches; the two inner run in the inner parenchyma and supply the proboscis, where they come into connection with some remarkable structures, namely, with two gelatinous, completely transparent and structureless columns, the function of which is altogether unknown.

New Form of Cestode, of the Type of the Cysticercus of Arion.[*]—M. A. Villot found this new form, which he proposes to call *Cysticercus glomeridis*, in a *Glomeris*; it is a small spherical body, about ·001 m. in diameter, consisting of two very different parts. There is a whitish transparent peripheral zone, and a brownish-yellow opaque central portion. The zone is a cyst, and the nucleus represents the head, body, and caudal vesicle of a *Cysticercus*; there is a proboscis, which is invaginated into the head, four suckers, a bulb, and a circlet of twenty hooks, which are arranged in two rows. Between the body and the cyst there is a cavity filled with liquid; the investing membrane is not fibrillar, but is rather made up of fine granulations, arranged in small groups and separated from one another by a hyaline border.

The cyst of the *Cysticercus arionis* has the same structure and the same function, and in it also the body is invaginated into the caudal vesicle. The differences between the two lie in the character of the cephalic armature; the discovery of the new form shows that the Arion-type is not confined, as Krabbe thought, to the Mollusca. It is possible that the *Tænia* is to be found in *Scolopax rusticola*.

New Form of Segmental Organ in the Trematoda.[†]—M. E. Macé finds this new type in a *Distoma* taken from the intestine of *Vespertilio murinus*; it is ciliated and single, a rather large cup-shaped organ being situated in the middle line, towards the posterior third of the body; in diameter it is almost half that of the ventral sucker, and its orifice is invested by long vibratile cilia; it gives off four vessels, of which the two superior pass upwards and are soon lost; the two inferior take a transverse direction, and, after a short course, open into the corresponding branch of the large terminal cavity of this apparatus. The *Distomum* in question has considerable resemblance to *D. ascidia*, but differs from it in some details.

Excretory Apparatus of the Turbellaria.[‡]—M. Francotte commences by referring to the discovery by Fraipont in the Trematoda of the ciliated infundibula of the excretory system of those animals, and states that he has been led to investigate the Turbellaria. In this preliminary communication he confines himself to *Derostomum* sp.

There are two principal longitudinal canals, which unite just above the pharyngeal bulb, by a transverse branch, in the centre of which is the external orifice of the water-vascular system. Posteriorly the canals unite to form a glomerulus, and within each of them one finds above thirty vibratile processes. Communicating with these canals and anastomosing with one another so as to form a plexus there is a system of much finer vessels; but in the terminal infundibula of these the author has not been able to detect any ciliation. The whole system of canals is filled with a clear liquid, the not numerous corpuscles in which are identical with those found in the

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[*] Comptes Rendus, xcii. (1881) pp. 418-20.

[†] Ibid., pp. 420-1.

[‡] Bull. Acad. R. Belg., l. (1881) pp. 30-4 (1 pl.).

lymphatic spaces. These lacunæ are found throughout the whole of the body and contain very small corpuscles; as they surround the enlarged extremities of the water-tubes the connection between the two is effected by the orifices in these latter, and the author has been able to see the corpuscles entering the tubes from the lacunæ. The lymph-spaces are regarded as the indications of a rudimentary cœlom.

Observations on the Orthonectida.*—Elias Metschnikoff describes a species which he found in *Nemertes lacteus*, where it forms under the skin a large number of rounded, pyriform, or irregular bodies, collected about the middle of the body only; their presence would appear to be the cause of the destruction of the generative organs of their host. In size they vary from 0·08 mm. to 0·2 mm., and the latter represent protoplasmic tubes in the interior of which there are a number of embryonic and mature Orthonectids. There are male, female, and hermaphrodite tubes, and the number of specimens found in one tube varies considerably. The larger forms, which have a close resemblance to the parasites figured by Keferstein and M'Intosh, are dark grey or dark brown by reflected light. Non-granular transparent lines give distinct indications of a segmentation, and in well-preserved examples nine segments can be made out. The whole of the upper surface is invested by delicate long cilia, which have a locomotor function; they fall off if the creature is kept for some time in sea-water. When treated with salt solution of a medium strength, and by sections prepared by Kleinenberg's method, and stained with borax and carmine, the following points may be made out.

There is an epidermic layer of a single set of cells, the constituents of which are generally cuboid in form and are richly granular; the cells bounding the segments have few granules and are broadened out. At the anterior pole of the body, and beneath the epidermis, there is an aggregation of small cells, which appears to represent the rudiment of some organ. The greater part of the body, that is the whole of its internal contents, consists of proportionately large cells, polygonal in form, with finely granular contents, and large round nuclei.

The smaller kinds have the posterior end rapidly tapering, and appear to move much more rapidly than the larger; there are at least eight ectodermal segments; in these, which are the males, the structure of the epidermis is more difficult to make out than in the larger females; numerous granules are to be found in it. The cells of the fourth segment are very long and extremely delicate. The interior of the body contains an oval sac, which extends from the third to the fifth segment, and is filled with small bodies, which seem to be zoosperms.

Some embryonic stages were observed; the youngest were seen to be rounded or oval cell-aggregates, the constituents of which were of two sizes; they appeared to form a solid morula, without any signs of a segmentation cavity, although such a cavity has, on previous occasions, been observed.

Nor has the author been able to make out the final fate of these

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* Zeitschr. f. wiss. Zool., xxxv. (1881) pp. 282–304 (1 pl.).

parasites; from the fact that in many cases the different sexes were found in different individuals of *Amphiura*, that in the plasmodium sacs no zoosperms were detected, and that the adults are able to live but a short time in sea-water, the author thinks it likely that fecundation is effected outside the body of the host, and a short time after the parents leave it.

If we sum up the characters of the Orthonectida we find them to be forms which generally exhibit a radiate plan of structure, have a ciliated and segmented dermal layer, well-developed generative organs with well-marked dimorphism of the sexes. They can only be placed with the Vermes on the supposition that that group does not represent a definite phylum. Metschnikoff thinks it probable that they are degenerated forms, and that their apparent simplicity of structure is a secondary result; this of course would make the question of their true relationship very difficult; they do not seem to have any close relation to the Dicyemida; the author is of opinion that Giard's idea of their affinity to the Rotatoria is not to be disregarded, but he himself would suggest the Turbellarian *Dinophilus* as their closest ally, for this form has a superficial ciliary segmentation and well-marked sexual dimorphism. The minute males are developed from special ova, which are smaller than those for the females, and within them the only evident organ is a spacious testicular sac. The topographical relations of their parts must not be regarded as definitely indicating any homology of germinal layers, and this remark may be extended to the Dicyemida. The theory of Rabl, which teaches that the direction movements of an animal in a confined space are to be associated with a radiate type, is not supported by what we know of these creatures; the Orthonectida—as indeed their name implies, and for this reason was given them by Giard—move in a linear direction, and yet exhibit a radial structure.

Systematic Position of Balanoglossus.*—Elias Metschnikoff returns to the view which he put forward twelve years ago, with regard to the close affinity between this curious "worm" and the Echinodermata. Such points as the two hinder circlets of cilia and the terminal anus are seen in some Echinoderms, and the latter is always found in the youngest stages of all typical Echinoderm larvæ. More important characters in common are found in the longitudinal band of cilia, the water-vesicle opening by the dorsal pore and the peritoneal sacs; in fine, the differences between *Bipinnaria* and a so-called vermiform larva of an Asteroid are more considerable than those between *Auricularia* and the larval *Balanoglossus*, which is known as *Tornaria*. The differences insisted on by A. Agassiz depended partly on his view of the characters of the water-vascular system, which the observations of Goette have shown to be erroneous.

Similarities do not, however, end here, for they extend to the details of histological structure. In both there are epidermal thickenings for the ciliary ridges, and the same kind of wandering

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* Zool. Anzeig., iv. (1881) pp. 139–43, 153–7.

mesodermal cells; musculo-epithelial structures give rise in both to the musculature of the water-vascular system, or, in other words, three muscular fibrils may, after treatment with osmic acid, be seen to be connected with the separate epithelial cells which invest the cæcal processes of the rudimentary water-vascular system. On this point the author insists in considerable detail, and concludes by stating that in the fore-gut of *Tornaria* one finds just the same fine fibrils of circular muscles which are so characteristic of the typical Echinoderm larva, and, as in them, that part of the gut is the only region which has a proper musculature.

The order in which the steps of metamorphosis are passed through is the same for the two sets of animals; for example, the longitudinal ciliated band arises before the anal circlet. A young *Tornaria* might be easily confounded with a young *Auricularia*, but never with a *Trochosphæra* or *Actinotrocha*. The supposition that there is a close affinity between *Tornaria* and the *Echinopædia* (or larval Echinoderms) is only possible on the view that there is nothing essentially different in their plan of structure. Nor is there; bilateral symmetry is typical of the Echinoderm larva, and persists throughout life in *Balanoglossus*. The water-vascular system, which is so eminently characteristic of the Echinodermata, is represented in *Balanoglossus* by the proboscis sac, which opens by a dorsal pore, and which, instead of growing out into radial prolongations, remains at a lower stage of development. If this view be correct, the so-called proboscis may be regarded as a single, conical, ambulacral tentacle; and it is not to be forgotten that in *Synapta*, which is a true Echinoderm, not only the ambulacral cæcal sacs, but also the longitudinal trunks are lost. The peritoneal system would also seem to be represented in *Balanoglossus*, and is lined by just the same kind of membrane as in the Holothurians, and the circulatory system in these Echinoderms is very similar to what is seen in *Balanoglossus*. The author looks upon the gills as rudimentary water-vessels delayed in development and undergoing vegetative repetition. The absence of calcareous matter from the integument of the "worm" is a notable point of difference; but, on the other hand, the nervous system is very similar.

As a result of his studies, the author proposes to form the "type" *Ambulacraria*, with the two sub-types of *Radiata* and *Bilateralia*. The former will include forms with a radial plan of structure developed on the bilateral embryo, with a greatly developed cutis, containing calcareous deposits and a complicated water-vascular system, arranged in a radial fashion. The latter retains definitely its bilateral symmetry, has no calcareous deposits, and has the water-vascular system less elaborately developed.

Echinodermata.

Arctic Echinodermata.*—Professor Martin Duncan and Mr. W. Percy Sladen have published (aided by a Government grant) an exact account of the thirty species found, chiefly by the officers of the 'Alert' and 'Discovery,' between 79° 20′ N. lat. to 82° 27′ N. lat. In

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* 4to, London, 1881, 82 pp. (6 pls.).

addition to the two forms, new to science, already diagnosed, Mr. Sladen describes a new Crinoid, to which he gives the name of *Antedon prolixa*. As a general conclusion of their studies, the authors find that the fauna with which they have had to do is essentially circumpolar; they give careful descriptions of what variations they have seen—variations which, with so great an area, may, of course, be considerable.

Echinoidea of the 'Gazelle' Expedition.*—This expedition brought back only forty-one species, of which, according to Professor Studer, seven were new to science. With regard to known species, the localities in the region of New Britain offer some interesting intermediate stations for those known to dwell in both the Pacific and the Indian Oceans. The 'Challenger' brought home one species of the genus *Catopygus* of the Secondary epoch, and Dr. Studer now describes a second. A fuller account is now given of the genus *Schleinitzia* (*S. crenularis*), which Studer named in 1876. The author directs attention to the crenulation of the tubercles in this and allied forms, and comes to the (to be expected) conclusion that the character is not one of generic value; he finds it to obtain when the spines are largely developed, so that the crenulation is comparable to the development of muscular ridges. *Astropyga elastica*, described in 1876, is now partially figured. An *Echinometra* was observed working on the chalk of a coral reef by its jaws. A new species, now for the first time described, is *Amblypneustes grossularia*, though the author thinks that it may be a young form (only a single specimen was found). He is not able to associate it with any of the species of which accounts have been given by Agassiz or Bell. The other new species are *Catopygus Loveni*, *Spatangus* (*Leucophorus*) *interruptus*, *Hemiaster florigerus*, and *Schizaster capensis*.

Locomotor System of Echinodermata.†—Messrs. G. J. Romanes and J. C. Ewart have especially devoted themselves to the ambulacral and nervous systems; they find that the former is shut off from the so-called blood-vascular system except at the madreporic plate. The latter communicates much more freely with the internal medium, a pressure of two feet during a number of hours being requisite to force the fluid injected into the stone canal through the madreporic plate. In *Echinus* lateral branches arise from the five radial nerve-trunks, and pass through the pores of the pore-plates. Each of these branches courses down a pedicel, and they give off other branches, which unite to form an intimate nerve-plexus which invests the whole external surface of the test, and passes to all the spines or pedicellariæ. Physiological, though no histological, evidence was also obtained as to the presence of a nerve-plexus on the inner surface of the test.

Experiments revealed "a high degree of co-ordination" in the natural movements of the Echinoderms; all, when inverted on a flat surface, are able to right themselves. "The common starfish does this by twisting the ends of two or more rays round, so as to bring the

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* MB. K. Preuss. Akad. (1880) pp. 861–84 (2 pls.).

† Proc. Roy. Soc. See 'Nature,' xxiii. (1881) pp. 545–7.

terminal suckers into action upon the floor of the tank, and then by a successive and similar action of the suckers further back in the series the whole ray is progressively twisted round." *Spatangus* uses its longer spines to push and prop itself.

Stimulation causes them (1) to escape from injury in a direct line from the source of irritation; (2) in a diagonal between two points; (3) there is a marked rotation on the vertical axis when several points all round the animal are simultaneously stimulated; (4) if a circular band of injury be made round the equator the animal crawls away from the broadest part of the band. When any part of the external surface is touched, the pedicels, spines, or pedicellariæ within reach close on the point; the pedicellariæ are the most active, and if they can they seize the body by their forceps; this observation leads us to see the function of the pedicellariæ. When climbing perpendicular surfaces of rock covered with waving seaweed an immediate hold is obtained, and the weed is held steady till the pedicels affix to it their sucking-disks; this last operation takes about two minutes, and this is about the time that the forceps are able to retain their grasp.

The spines bristle when the surface of an echinus is severely irritated; the pedicels of a given row are retracted when irritation is applied to that row. Irritation of the external plexus stimulates the pedicels, but the former, or inhibitory, action is the stronger of the two. Unless the eye-spots are removed, Asterids and Echinids crawl towards light.

Single rays crawl as fast and as regularly as entire animals, are affected by light, crawl up perpendicular surfaces, and are able to right themselves. When the nerve-ring is severed at its centre, the rays act independently; but this mode of section does not seem to affect the physiological continuity of the external nerve-plexus, which would seem to connect with one another all the pedicels and muscles without any reference to the main trunks. Injury of the external plexus destroyed "the nervous connections on which the spines and pedicellariæ depend for their function of localizing and closing round a seat of stimulation," but it does not destroy that co-ordination of the spines which is necessary for locomotion; the seat of this influence would appear to lie in a not yet observed internal plexus. A proof from the physiological point of view is found in experiments by which the whole of the internal surface of the test is completely cleaned; after this the spines and pedicellariæ shortly become perfectly quiescent, to feebly recover themselves after a few hours. This "hypothetical internal plexus" would appear to be in close connection with the external plexus.

Echini may be divided, and the pieces, however small, still exhibit local reflex irritability. In the righting action the pedicels would appear to act serially, and to be assisted by nervous co-ordination. Removal of the pentagonal nerve-ring has no effect on the pedicellariæ or on the local reflex action of the spines, though the general co-ordination of these latter is completely destroyed: this nerve-ring has, in effect, the function of a nerve-centre. And, on the whole, it is found that the "nervous system is in function, as in structure, everywhere both central and peripheral;" the ring has only a more centralizing influence than any other part of the nervous system.

Circulatory and Respiratory Organs of the Ophiuroidea.*—M. N. Apostolides, by injecting several species, finds that after successful injection of the aquiferous system, and on dissection of the interbrachial space of the madreporic plate, he meets with a dilated whitish canal, the walls of which are kept rigid by calcareous plates. On opening this canal there is seen, near the middle, a brownish mass—the so-called heart, and by its side is a thread-like tube—the true sand-canal, containing the injection. The so-called heart is independent of the water-system, while the delicate canal allows this system to communicate with the exterior. A careful dissection of the "heart" shows that it is elongated and continued into a canal which passes to the madreporic plate, on which it opens; its structure reveals it to be a gland, with an excretory canal. On each side of it there are two small fibrous bands, which pass laterally to the base of the arms; like the bands which support the Polian vesicles, they are coloured by hæmatoxylin, but the liquid injected into the "heart" never passes to them.

If the injection enters between the integument and the digestive tract, that is, into the body-cavity, it is never seen on the exterior, and does not penetrate into the water-system; the body-cavity, then, is entirely closed; it consists of an enlarged portion which surrounds the digestive tube, and of a flattened portion which is found in the dorsal region of the arms. There is also a perineural space, as well as a radial cavity, and these enter into communication with the general cavity; there is no system of canals proper.

A living animal may be observed to dilate and contract its dorsal surface, and if colouring matter be put into the water, a double current may be seen around the genital clefts. If a coagulable liquid be injected by one of these, it is seen that the cleft opens into a large and completely closed sac, which is dilated in the ventral and diminished in the dorsal region; these sacs, to which Ludwig has given the name of bursæ, have so close a relation to the nutrient fluid of the general cavity that they ought to be considered as respiratory sacs; the blood would appear to be drawn into the cavity around the digestive tube ("peristomachal space") by the alternate contraction and dilatation of the sacs.

Stomach and Genital Organs of Astrophytidæ.†—Under the above title Professor T. Lyman gives an account of his observations, to which he was led by making a section of a gravid *Gorgonocephalus Pourtalesi* of the 'Challenger' collection: "My astonishment was considerable when there was brought to light an internal economy which reminded one rather of an orange than of an Echinoderm. A horizontal cut, just above the joint of the radial shields, disclosed a quantity of membranous partitions stuffed with a sort of pulp and radiating in a confused manner; while a vertical section showed a

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* Comptes Rendus, xcii. (1881) pp. 421–4.

† Bull. Mus. Comp. Zool. Camb., viii. (1881) pp. 117–25 (2 pls.).

cavity, which might be the stomach, surrounded by and communicating with a number of convolutions or blind sacs. The matter became clear only by giving up the idea that a strict correspondence with known forms was to be looked for."

The stomach is not simple, but passes upwards into a number of membranous pouches, which are attached to the roof of the disk-wall, to the inner points of the ovigerous lobes, and powerfully by ten points which encircle the mouth. These last are brachial or interbrachial; immediately above the attachment of the latter there is a much folded and fluted interbrachial stomach-pouch; similar to its attachments are those of the brachial pouches, and the whole arrangement would divide the body-cavity into "ten radiating compartments completely separated from each other, were it not that an open space exists between the inner point of each attachment and the stomach-sphincter." This space would seem to correspond to the inner perihæmal canal, described by Ludwig as existing in the Ophiurida, but it differs from it in not being closed.

The ovaries are formed by deep, lobed, and contorted folds of the lining membrane of the disk-wall on its floor, sides, and part of its roof, so that there are no closed bursæ, but the entire body-cavity, with the exception of the just mentioned perihæmal ring, is also the genital cavity. The eggs would appear to be impregnated in the body-cavity. A description of a non-gravid *Euryale* is given, and it is pointed out that the genital openings can be contracted or expanded; in the membrane lining the compartments the author found fragments of "microscopic limework" comparable to those found in the walls of the bursa of *Ophiura lævis*, and which, when further developed, form the thin scales found in the walls of the bursæ of *Ophiothamnus vicarius*.

Passing from the true Astrophytons, we find in *Astrocnida isidis*, "a curious and quasi-intermediate structure." The stomach was, as in Ophiurids, entirely free below, and there were no radiating lines of attachment save the stout septum, which is also seen in Ophiurids. The ovaries were arranged on the type of *Astrophyton*. Very similar arrangements obtain in *Astrogomphus*. *Ophiocreas œdipus* is much more Ophiurid. There is a distinct bursa, and the position of the genital organs between the skin of the arm and the arm-bones is only due to the smallness of the disk and body-cavity.

Although we have, therefore, a series of stages, Mr. Lyman is of opinion that *Ophiocreas* is not an *intermediate* but a *synthetic* form. "It has the teeth of *Euryale*, the pleated stomach suggestive of *Gorgonocephalus*, the genital bursa and ovarial tubes similar to, yet not the same as those of Ophiurans in general, the arm-plates that recall Ophiomyxa; nay, one Astrophyton character, the adhesion of the stomach to the disk-wall, is carried further than in Astrophyton itself."

Preliminary List of the known Genera and Species of Living Ophiuridæ and Astrophytidæ.[*]—Professor L. Lyman has added

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[*] 4to, Cambridge, U.S.A., 1880. 45 leaves, printed on one side only.

another to his many services to the students of this group of the Echinodermata by the publication of this list, in which, in addition to the names, we have localities, and a statement of the depth at which the species have been found, as well as references to the principal synonyms and authorities; there is further a shorter list of the more important works on the subject.

Cœlenterata.

Nervous System of the Siphonophora.*—Dr. Chun, attracted by the fact that among the Cœlenterata the Hydroid Polyps are the only forms in which no indications of a nervous system have yet been made out, has applied himself to the study of the Velellidæ, and has been rewarded by the discovery of a quite typically differentiated plexus of branching and intercommunicating ganglion-cells. To make the relations of this system clear he gives a sketch of the structure of these Siphonophora, into which we cannot here follow him. Subjacent to the whole of the outer ectodermal lamella, there is a plexus of ganglion-cells; they are only absent where the ectoderm secretes a chitinous support for the air-sac. The cells generally have three or four processes; more or fewer are rare; the cell itself is almost completely filled up by the finely granular nucleus; the processes rapidly begin to divide into smaller branches, which again give off a number of lateral branches. The whole is characterized by the straight course which the branches take; they are not waved or bowed; freely ending fibres are very rare, for they nearly always unite with the corresponding fibres of other cells. The author was not able to detect any larger marginal nerves made up of smaller fibres, nor any sign of endodermal nervous elements. A further proof that the bodies in question are nervous would appear to be afforded by the fact that there is in them no true connective tissue; this is probably due to the development of chitin.

Colouring Matter of Medusæ.†—Professor M'Kendrick has investigated the properties of the colouring matter of some of the British jelly-fishes—the beautiful blue *Cyanea; Chrysaora*, distinguished by the patches of brown around the tentacles and the margin of the umbrella, and in the long arms; and *Aurelia*, with the crescentic masses of colour around the ovaries.

By microscopical examination ($\frac{1}{15}$ in. × 1200) he ascertained that the colouring matter is not uniformly distributed throughout the protoplasm, but that it exists as little irregularly-shaped particles in the protoplasm of minute cell-like bodies. These granules were about $\frac{1}{30000}$ in. in diameter; in *Chrysaora* of a yellowish colour, while in *Cyanea* they had a faint tinge of blue. The surrounding protoplasm was colourless.

It was then attempted to extract the colouring matter. Cutting off the coloured fringes of *Chrysaora*, portions were placed in (*a*) strong caustic potash; (*b*) absolute alcohol; (*c*) sulphuric ether; (*d*) in sea-water. In about an hour the portions in potash were

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* Zool. Anzeig., iv. (1881) pp. 107–11.

† Journ. Anat. and Physiol., xv. (1881) pp. 261–4.

broken up into dark brown shreds, whilst the fluid remained colourless. No effect was produced by absolute alcohol or by ether, but the colour in the fragments in sea-water diffused out to a considerable extent in twenty-four hours. The fluid then was dark brown; pressure caused no separation of the colouring matter.

Boiling caused the colouring matter to diffuse out quickly, and on filtering the fluid it was found to be acid and of a dark brown colour. The colour at once disappeared on the addition of strong sulphuric acid; strong nitric and strong hydrochloric acids produced the same effect, but not so quickly. Strong caustic potash caused a reddish-brown precipitate, but as the fluid consisted of sea-water, a portion of the precipitate must have consisted of the hydrated oxides of lime and magnesia in the water.

As regards *Cyanea* and *Aurelia*, neither pressure, boiling, nor mineral acids, alkalies, alcohol, or ether, dissolved out the colouring matter. The only way of obtaining it was to allow fragments to macerate in sea-water for about thirty-six hours. Then the fluid became sky-blue when *Cyanea* was used, and slightly pink with *Aurelia*. The colouring stuff could not be extracted from this fluid by alcohol or ether, but was thrown down by an alkali. On adding ammonia to any coloured infusion of jelly-fish, a copious precipitate falls, which carries with it the whole of the colouring matter. After filtration the fluid is quite colourless, and the colouring matter remains on the filter. Again the precipitate is readily redissolved by acid, and the colouring matter passes into a soluble state. It is soluble therefore in an acid medium, but insoluble in an alkaline or neutral medium. Now fresh jelly-fishes, so far as the author could make out, were quite neutral to test paper; he could not find any alkaline reaction. But in the living jelly-fish we can scarcely suppose that the colouring matter exists in the granular form simply because the medium is alkaline or neutral; all we can state is that the medium is neutral, and the probability is that the colour stuff is formed in the protoplasm of certain cells, just as pigment is formed in the cells of the epidermis of many animals. After the death of the jelly-fish, however, the body becomes slightly acid, the protoplasm disintegrates, and the colouring matter diffuses out. During life a muscle is slightly alkaline or neutral; after death, when rigour sets in, it becomes acid.

The colouring matter was also examined with the spectroscope; it was found that infusion of *Chrysaora* gave no distinct absorption bands; but the violet, blue, and a portion of the green were absorbed, the other colours being slightly reduced in intensity. On concentrating the fluid, the red, yellow, and what remained of the green, became very dim, but no bands appeared. With *Cyanea*, however, an infusion gave two distinct absorption bands, one in the red, and the other in the orange. The other blue colouring matters hitherto met with in the animal kingdom are the blue colouring matter obtained from *Stentor cœruleus*, described by Lankester,* which gives two absorption bands nearly the same in position as those in

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* Quart. Journ. Micr. Sci., xxi. (1873) p. 139.

Cyanea, and a blue matter called *hæmocyanine* found in the blood of the *Octopus*, which, however, has no definite absorption bands.*

Australian Distichopora.†—Though the title of this paper by the Rev. J. E. Tenison-Woods is "On the Anatomy of Distichopora, with a Monograph of the Genus," it is rather a descriptive list of the Australian living *Distichopora* than a paper on their anatomy. As a list, however, it is very useful to all studying the Hydrocorallinæ, as the work already done is well reviewed. The references are full, ranging from those of Pallas, Blainville, Lamarck, Milne-Edwards, Agassiz, &c., up to the more recent observations of Mr. Moseley, whose classification is adopted. There appear to be eleven species known to be living in the Australian seas.

Observations on Hydroid Polyps.‡—Dr. A. Weismann, in directing attention to the pulsation of the body of Hydroids, points out that it is not correct to suppose, as is generally done, that the circulation of the fluid in the body is altogether effected by the flagella of the endodermal cells; at certain points the body-wall contracts rhythmically. This was first seen in the gonophores of *Coryne pusilla*, when the author was attempting to draw them. Closer examination showed that the endodermal tube alternately enlarged and contracted; in the systole the cavity of the gonophore became invisible and the walls of the endoderm came together. From what the author has seen he concludes that there is a muscular layer between the endoderm and the mass of genital products, and this band becomes thicker during the systole.

In Plumulariidæ and Campanulariidæ the author finds that the musculature is not, as has been supposed, confined to the hydranths, but that it extends over the whole trunk and all its branches; everywhere there is a single layer of elongated, spindle-shaped muscular fibres, lying above the supporting lamella. In *Plumularia*, at any rate, it consists of independent nucleated cells, which at most points form a regular simple layer around the endodermal tube; its function would appear to be to aid in the circulation of the blood.

As to movements of the ectoderm, Dr. Weismann finds that the processes by which the polyp is attached to its tube are during life in nearly constant movement, which is slow and amœboid, but not passive, as is shown by the fact that new processes of attachment may become developed, fine filaments of ectoderm gradually growing larger and thicker. There is therefore a close analogy with the pseudopodial processes by means of which some Rhizopods are attached to their shell.

Formation of Ova in Eudendrium.§—In a further note Dr. Weismann points out that the differences between the account he now gives and that which he gave on a previous occasion are due to the fact that different species were under observation. In *E. racemosum* Cav. the egg-cells are formed in the ectoderm of the cœnosarcal tube, and, at a

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* See this Journal, ii. (1879) p. 164.

† Journ. R. Soc. N. S. Wales, xiii. (1879) pp. 49–63 (2 pls.).

‡ Zool. Anzeig., iv. (1881) pp. 61–4.

§ Loc. cit., pp. 111–14.

certain age, make their way into the endoderm; in *E. ramosum* they are developed in the endoderm. The author considers that if two species of the same genus act thus differently the origin of the generative products from one or other germinal layer is not a matter of prime importance. It may, however, be suggested that a difference of this kind is of importance enough to justify the generic separation of the two species in question, and it does most certainly bring to the front again the vexed question as to the real value of the characters on which genera and species are so frequently established.

Porifera.

New Lyssakine Hexactinellid.*—Professor Sollas describes a new fossil Hexactinellid sponge from the Niagara chert beds of Hamilton, Ontario. It is the second oldest known example of the Lyssakina. The author proposes for it the name of *Astroconia Granti*, the former in allusion to the peculiarly spinose character of the rays of the sexradiate spicules. The anchoring spicules consist of a straight shaft with four recurved rays, each having a small bifid spine near the base on the outer surface. It is the next oldest sponge to *Protospongia*.

Fossil Sponge Spicules.†—The chalk-pit at Horstead, Norfolk, contains many large variously-shaped nodules of flints, strewn about after the removal of the soft chalk in which they had been imbedded. One of these, about a foot in diameter, and more spheroidal than the generality of the potstones, attracted the attention of Dr. G. J. Hinde. It exhibited a central cavity, which contained a quantity of material resembling fine flour in appearance and feel, and of a creamy white tint. The material, when prepared for examination, weighed about three or four ounces.

The author describes, from it, 160 forms of spicules, which he refers to thirty-eight species and thirty-two genera of sponges, fourteen of the species belonging to the Lithistids and Hexactinellids. Besides the spicules of sponges, there were in the cavity remains of Foraminifera, Ostracoda, Echinodermata, Annelida, Cirripedia, Polyzoa, Brachiopoda, Lamellibranchiata, and Fishes, the first two kinds, with the sponges, being far the most abundant. The abundance of the sponge spicules sustains the author's conclusion that flint nodules of the chalk have resulted from the aggregation of the siliceous spicules or skeletons of the sea-bottom sponges, as the chalk from an aggregation of the shells of Foraminifera, Ostracoda, and other calcareous secretions of the same seas.

Protozoa.

Bütschli's 'Protozoa.'—The sixth and seventh parts of this publication have been issued; they consist chiefly of the "system" of the Rhizopoda, but have also some remarks on the habits of life, mode

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* Abstr. Proc. Geol. Soc., 1881, pp. 50–1.

† Hinde, G. J., 'Fossil Sponge Spicules from the Upper Chalk, found in the interior of a single flint-stone from Horstead in Norfolk,' 83 pp. (5 pls.). (8vo. Munich, 1880.)

of nutrition, and on the dependence of their organization on external conditions. With regard to this last, it is pointed out that the Imperforata grow smaller at greater depths; as to the Perforata, the same is partially true, but late investigations show that temperature has no inconsiderable influence. The composition of the water has an influence on the characters of the shells. In the discussion on *Bathybius*, Haeckel's opinion that *Bathybius* is only found locally and is confined to the northern seas, is quoted. It is believed that Bessel's account is worthy of all confidence; but it is pointed out that in the original Bathybius-slime Gümbel found only 3·05 per cent. of organic matter, and no sulphuric acid at all.

The Rhizopoda are divided into the sub-orders (1) Amœbeæ and (2) Testacea; and an account is given of *Eozoon* (the verdict on which is left to the reader, though the author inclines to the view of its being inorganic) and of the Stromatoporida.

Acineta dibdalteria, a New Species of Marine Infusorian from the Gulf of Genoa.*—Dr. C. Parona describes a new *Acineta*, of peculiar characters, especially in regard to the suckers, which are not borne by a trunk, and are not ramified. It is solitary and attached by means of a slender peduncle to various marine Algæ, and is tolerably abundant. The suckers were found to be very remarkable. Instead of being collected into bundles and arranged symmetrically on one side and the other of the body, or distributed over the whole of the free surface of the protoplasm corresponding to the aperture of the test, they are only two in number, placed opposite one another. Whilst in the other *Acinetæ* these sucking tentacles are slender, more or less long, and usually rigid; in the new species they are flexible in all directions, and very mobile, so that they move and twist about continually.

The author has not met with these characters in any other *Acineta* hitherto described, and therefore proposes to establish, if not a new genus (so as not to complicate further the divisions of the group), at least a new species, under the name of

Acineta dibdalteria sp. nov.—Diagnosis:—Test in the form of a wine-glass; peduncle slender; tentacles single; protoplasm granular, more transparent at the periphery; contractile vesicle large; nucleus in the shape of a horseshoe, and placed towards the lower part of the protoplasmic mass. Only two tentacles, which are at the same time suctorial and prehensile, movable in all directions; peduncle straight, slender, of uniform diameter, and only a little widened towards the base to attach itself more firmly to the plant which bears it.

Dimensions.

	Mm.
Transverse diameter of the test (maximum)	0·06
Vertical diameter of the test	0·05
Length of the peduncle	0·03
Breadth of the peduncle	0·01
Length of the suckers..	0·04

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* Arch. Sci. Phys. et Nat. (1881) p. 181. See Ann. and Mag. Nat. Hist., vii. (1881) pp. 279–80.

We have here a very remarkable example of anatomical and functional retrogression. The organs having been reduced, the functions have been concentrated. The differentiation of the suctorial and prehensile tentacles having ceased, or being absent, the two correlative functions have been compelled to combine in the same organ, which, in its turn, in order the better to perform its now multiple part, has been obliged to modify and adapt itself. We have evidence that this must have taken place when we find that whilst in the other *Acinetæ* the tentacles are usually rigid and motionless, in the present case they are flexible and movable in all directions.

Foraminiferous Silt Banks of the Isle of Ely.—Mr. James Green, of March, describes these banks as follows:—

In various parts of the fens of Cambridgeshire, but more particularly in the district known as the Isle of Ely, may be found considerable beds of silt, which give a slightly undulating surface to what would otherwise appear as a perfectly level plane. These banks are generally covered with from one to two feet of the ordinary black vegetable mould, for which these fens are particularly famous. Occasionally the silt crops out, and where this is the case it almost assumes the same colour as the surrounding earth. The height of the banks rarely exceeds four or five feet. In the town of March there is a fine sample of one of these silt banks, which has been opened, and large quantities of the silt taken away by brickmakers, to prevent the newly made bricks from adhering one to another before being dried and burned. They have left a large semicircular section of the silt upstanding, somewhat like a wall some four or five feet in height. The beds rest, in most cases, on blue clay, which extends downwards, as far as any local borings have ever been made, some fifty or sixty feet. On carefully examining the section, one may trace thin sinuous lines of a black or greyish tint, running in a nearly horizontal direction, resembling the ripples left on the sand at the sea-shore. The lines were apparently formed in some such manner, as on examining them with a powerful hand-lens large numbers of Foraminifera are seen, which are, in fact, almost exclusively confined to the sinuous lines, the bulk of the silt itself (which is of the colour of yellow ochre) containing none. These greyish lines consist for the most part of shells, fine sand, black specks of what seem to be lignite, and other decayed matter, such as one would expect and *would* find in the ripples by the shore.

Mr. Green adds that if any difficulty is found in getting heavy shells to swim by the floating process, strong brine will often accomplish what the fresh water fails to do.

Production of Amœbæ.[*]—Professor Nunn gives an account of a discovery she has made of the generation of *Amœbœ* in a remarkable manner from an infusion of the yolk of a hen's egg in Pasteur's fluid. In about ten days, and when the odour of decomposition had begun to be strong, *Amœbœ* were found in such abundance as to form a creamy deposit on the surface of the liquid, and a drop examined from any

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[*] Amer. Journ. Micr., vi. (1881) p. 24.

part of the fluid showed hundreds in the field. They varied greatly in size, and had a remarkably active amœboid movement. Generally a nucleus in vacuo could be distinctly seen. They seem not to make their appearance in water and egg alone, and apparently flourish best when ammonium tartrate is replaced by pepsin.

New Rhizopoda.*—M. A. Korotneff describes some new forms, the first of which he calls *Protamœba primordialis* (n. gen. et sp.); the name *Protamœba* has, however, been already used (see, e. g. Macalister, Introd. Anim. Morph., p. 49, fig. 1); this new form is one of the Monera.

The next new genus is *Dactylamœba elongata* (Pl. VI. Fig. 1 × 540); its elongated body is divided into an anterior portion which is perfectly transparent, and a posterior which is granulated; in front we find long conical pseudopodia directed forwards. In the hinder part there is a central granular mass, containing brown elements, while the peripheral envelope is hyaline and gives off short, obtuse, or even lobate pseudopodia. Quite at the extremity there are small delicate prolongations which appear to serve as points of support for the animal. There are two vacuoles which pulsate alternately. The whole creature is only 0·13 mm. in length.

Longicauda amœbina (n. gen. et sp.) (Fig. 8 × 540) is a form with a reniform nucleus, which has a well-marked contour, though no envelope could be demonstrated; there is a tail made up of three completely independent parts, which ramify like a deer's horns; the branches retain their form, owing to the presence of a firm envelope, so that they are permanent pseudopodia.

In the genus *Pelomyxa*, the author describes a new species, *P. parvialveolata*, and gives some notes on the history of *P. palustris* Greef; he finds himself in general agreement with the German observer. Within the substance of the *Amœba* in question are found (Fig. 2 × 1100) shining bodies, altogether hyaline in character, rounded in form, and varying in size (from 0·005 mm. to 0·008). These bodies elongate, become biscuit-shaped, and divide into two spheres. When they are beginning to undergo a change they enlarge at one point (Fig. 3) and become filled with the protoplasm from the body; thus growing they become spherical (Fig. 4), leaving a small orifice for the entrance of the protoplasm; meantime the walls swell, and soon the orifice becomes closed up (Fig. 5). In one specimen of *Pelomyxa* the author found a number of spherical capsules completely closed, and with delicate, highly refractive walls. Within this capsule there was a finely granular plasma, and a small rounded body which appeared to be a "shining body" (Figs. 6 and 7); these capsules were distinguished by the presence of a vacuole, but the author was unable to follow their history any further. He is, however, of opinion that, as Greef thinks, the shining bodies are the spores which give rise to young *Amœbæ*.

The author concludes with some remarks on *Cochliopodium* and on the development of *Acanthocystis viridis*, where he finds that the small ovoid bodies described by R. Hertwig are true embryos.

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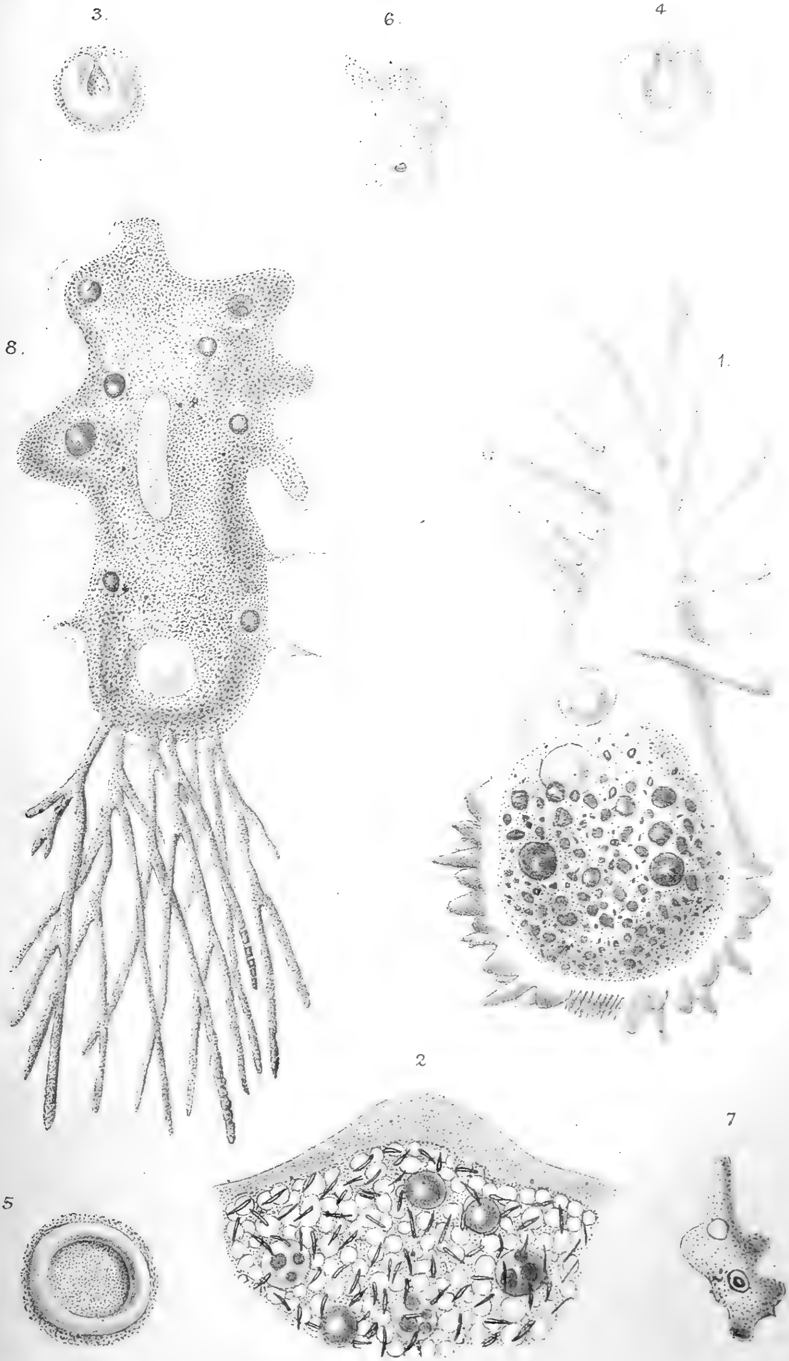
* Arch. Exp. et Gén. Zool., viii. (1880) pp. 467–83 (2 pls.).



RHIZOPODA.

West, Newman & Co. lith.

Fig. 1. Dactylamœba elongata.
Figs 2–7. Pelomyxa palustris.
Fig. 8. Longicauda amœbina.

BOTANY.

A. GENERAL, including Embryology and Histology of the Phanerogamia.

Structure of Protoplasm and of the Cell-nucleus.*—F. Schmitz has applied to the examination of vegetable protoplasm the mode adopted in animal histology, of hardening and afterwards colouring, by which the finer structure can be detected, as already described by Frommann.†

The protoplasmic body consists of a reticulated framework of extremely fine fibrillæ, varying much in their development. Even in the youngest meristem-cells the protoplasm is not uniformly dense; the peripheral layers are finely dotted, while towards the middle are larger or smaller homogeneous lacunæ, bounded by finely dotted plates, bands, or very delicate threads of protoplasm, the number of the lacunæ continually increasing with the age of the cells. Subsequently they increase also in size, and frequently coalesce with one another, until finally the protoplasm is reduced to a parietal utricle, with a larger or smaller number of bands or threads crossing the cell-cavity. The thicker bands and the parietal layer clearly manifest the reticulated structure. Imbedded in the protoplasm are almost always small strongly refractive granules, which assume a darker tincture—the "microsomes" of Hanstein, which the author regards not as metaplasmic enclosures, but as essential constituents of the protoplasmic body itself. The intermediate substance between the meshes of the fibrillar framework is a homogeneous fluid. The separate meshes are in open communication with one another. When a large central vacuole has been formed, the adjacent innermost layers of the fibrillar network often form a special darker bounding-layer, in consequence of becoming closely applied to one another. In those cells the membrane of which has undergone a partial thickening in the form of spiral or reticulate ridges, as well as in those numerous cases where the cells, when old, completely lose their protoplasm, the protoplasmic utricle is at first always thinner, is detached with greater difficulty from the cell-walls by contracting reagents, until at length only isolated portions and the nucleus remain, the latter being firmly attached to the cell-wall; the substance of the protoplasmic utricle is gradually used up in the thickening of the cell-wall. The framework of fine fibrillæ does not consist of rigid immotile fibres, but of a living motile protoplasm, which is continually undergoing change of form.

The cell-nucleus consists of a matrix, in which, after hardening and colouring, a very fine punctation can be recognized, probably due (as in the protoplasm generally) to a similar reticulate structure. The nucleus is often bounded on the outside by a special layer, in the

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* SB. Niederrhein. Ges. Natur. u. Heilkunde, Bonn, 1880. See Bot. Centralbl. i. (1880) p. 1294.

† See this Journal, iii. (1880) p. 823.

denser substance of which a number of densely packed granules are frequently imbedded. These granules, which assume a deeper colour under tincture, and which vary greatly in size, form, and number, have been termed by Flemming "chromatin-granules"; the larger of these have been long known as nucleoli. These chromatin-granules certainly sometimes multiply by division; possibly, also, by new formation. Whether they are essential constituents of the nucleus, or only enclosures, is doubtful. The nucleus always multiplies by division, and, in all observed cases, by bipartition, although the details vary greatly in different cases; but the various modes graduate into one another, and may be regarded as modifications of one and the same process.

In the simplest case, the mature nucleus simply undergoes transverse division, without any striking change in its chromatin-bodies; only an inconsiderable change in its internal mass is indicated by the longitudinal streaking of the matrix. In other cases, simultaneously with the division of the entire nucleus, the chromatin-bodies also divide, with changes in form more or less complicated. With this is combined the additional phenomenon, that the mass of the old nuclei is not identical with that of the two daughter-nuclei; but that a considerable portion of its matrix, usually displaying obvious longitudinal fibrous structure, is eliminated, and incorporated with the protoplasm-body of the cell, while the chromatin-bodies of the old nucleus, divided into two groups, together with a portion of the matrix, become differentiated into two daughter-nuclei. Finally, in the most complicated case, the differentiation of the matrix of the nucleus from the surrounding protoplasm is lost almost from the first, and a fibrous differentiation, like that in the matrix of the nucleus, is exhibited also in a larger or smaller portion of the surrounding protoplasm; and finally, each of the two groups of chromatin-bodies of the old nucleus, with a portion of this fibrous protoplasm, separates into a daughter-nucleus, while the remainder of it, with the rest of the surrounding protoplasm, forms the protoplasm-body of the new cell.

This last mode of division of the nucleus occurs in the meristem of the Archegoniatæ and Phanerogams, where a rapid increase of the protoplasm is necessary for the great multiplication and increase in size of the cells. The author believes that the matrix of the nucleus is probably only a denser portion of the protoplasm-body itself, adapted to special physiological functions.

With reference to the relation of the nucleus to the entire cell, the author states that the dissolution of the two usually coincides in time; it has already been shown that previous statements of a disappearance of the nucleus in the living cell rested on erroneous observations. Where the nucleus displays motility, this is, in all observed cases, only passive; there is never any active change of position. The cell-nucleus must therefore be regarded as a differentiated portion of the protoplasm-body of the cell, differing slightly in its substance from the surrounding protoplasm, and containing in its interior structures, varying in number and arrangement, but very rich in protein, the chromatin-bodies; its special function is, apparently, the new formation of the proteinaceous substance.

Finally, the author proves the existence of nuclei, sometimes singly, sometimes several in a cell, in groups of Thallophytes where they were previously stated not to exist, especially the Basidiomycetes and Ustilagineæ. The Phycochromaceæ were found to be destitute of a nucleus.

Crystalloids in the Cell-nuclei of Pinguicula and Utricularia.*—In pursuance of his investigations of the crystalloids of *Pinguicula alpina*, J. Klein has carried them further in this species, as also in *P. vulgaris* and in *Utricularia vulgaris*. In *Pinguicula* the crystalloids are formed in the cell-nuclei of the epidermal cells, especially those of the pedicels of the stalked glands on the lower part of older leaves. In these cells the protoplasm is divided into fine branched threads proceeding from the nucleus through the cavity, and manifests a slow motion in which the nucleus also participates. The crystalloids occur also in the cells of the mesophyll, but are more difficult to detect, being mostly concealed by the numerous chlorophyll-grains, and in the flowers as well as in the young cells of the glands.

As to their form, when in a certain position the crystalloids appear cubical, while the nucleus is spherical. In other positions they have a more or less narrowly rhomboidal or needle shape; whence their true form would appear to be that of thin square plates. They are very minute and seldom single, more often twenty or more in older cells. The size of the nucleus varies with the size and age of the cells; its largest diameter attains from 0·016 to 0·024 mm., and it may contain from ten to twenty crystalloids; the connected mass of crystalloids has, in some cases, a length of 0·04, and a breadth of 0·012 mm.

When young, the nucleus is homogeneous, and contains no crystalloids; only a small nucleolus; when, at a later period the crystalloids have formed, the nucleolus is no longer directly visible, but is revealed by treatment with certain reagents which dissolve the crystalloids. On treatment with alcoholic solution of iodine, the crystalloids disappear, and the nucleus becomes more sharply defined, and of a yellow colour. Concentrated solution of sugar causes the crystalloids to coalesce into a homogeneous mass; subsequent addition of concentrated sulphuric acid colours the nucleus a beautiful rose-red, showing that the mass of crystalloids contains proteinaceous substances.

The crystalloids of *Pinguicula alpina* are somewhat more persistent, since occasionally, in older cells, they are not changed by alcoholic solution of iodine, concentrated solution of sugar also having various effects on them.

In *Utricularia vulgaris* they present a general similarity to those of *Pinguicula*; but the nucleus is much smaller. They occur in the cell-nuclei of the walls of the bladders, and in the trichomic structures of the bladders; also in the chlorophyll-containing cells of the leaves

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* Bot. Centralbl. i. (1880) pp. 1401-4.

and branches. Here also they appear to have a narrow, square, tabular form, the nucleus being again spherical. Their reactions agree in general with those of *Pinguicula*.

In general terms the crystalloids in these plants agree, in their character and qualities, with those of *Lathræa squamaria;* all the plants containing them being distinguished by a peculiar mode of life.

Tegumentary System of Roots in Phanerogams.*—L. Olivier publishes a preliminary notice of the chief points arrived at in a study of this structure in the roots of Monocotyledons, Gymnosperms, and Dicotyledons.

In Monocotyledons the peripheral layer of the root is usually, with some exceptions, simple; with the exception of the production of rootlets, it does not give rise to any tissue. There is no true epidermal layer; that which is usually so termed, and which is commonly piliferous, is not continuous anatomically with the epidermis of the stem, but is covered by a cap, one of the layers—and not always the outermost—of which corresponds morphologically with one of the sub-epidermal layers of the tigellum. In the great majority of cases, the mode of formation of the stem is more or less centripetal.

In Gymnosperms—contrary to what occurs in Monocotyledons—the primary cortex does not give rise to any tissue, and it is the rhizogenous layer that produces a secondary parenchyma towards the interior, the bark towards the outside.

Among Dicotyledons the secondary tegumentary structures vary in their development according as the secondary vascular system is formed early or late, as the plant is herbaceous or woody, and as the root is aerial or terrestrial. A variety of cases are described differing from one another in these points; and the following are the more important results arrived at, where the secondary vascular system is formed early.

1. The peripheral layer of the central cylinder forms beneath it a centrifugal secondary parenchyma.

2. When the formation of this parenchyma becomes appreciably unequal, as in the bean, the rhizogenous layer commences to divide in order to give birth to the primary vascular bundles.

3. This secondary parenchyma and the primary cortical parenchyma are always composed of large cells whose walls are coloured blue by chlor-iodide of zinc, and are full of protoplasm; they continue in an active state during the whole life of the root when it is annual; a large quantity of nutritive reserve-materials is stored up in them, with which they are always gorged in winter.

4. Normally the root has no suberous layer; such is formed from the bark only in a very irregular and accidental manner, and only in those cases where the external primary cortical layers peel off.

5. All the species of Dicotyledons observed were herbaceous; in woody plants the phenomena presented differ in many points.

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* Bull. Soc. Bot. France, xxvii. (1880) pp. 233-41.

Growth of Cuttings.—Mr. Francis Darwin recently read two papers at the Linnean Society, on "The Power possessed by Leaves of placing themselves at right angles to Incident Light," and on "The Theory of the Growth of Cuttings, illustrated by observations on the Bramble." Abstracts of the papers have already been published in the journals to which references are given in the footnote.[*]

Function of Chlorophyll, and its relation to Light.[†]—In pursuance of his previous investigations on this subject,[‡] Professor Pringsheim publishes the results of a new and elaborate series of observations.

He here adopts a method of separating the colouring matter, together with the fluid or semi-fluid substances which accompany it, from the matrix of the chlorophyll-grain, without the application of any solvent. This is effected by means of a dilute acid, especially hydrochloric acid, or of the application of a moist heat, as by subjecting them to warm water or to the vapour of boiling water. The residue of the chlorophyll-grain then consists of a skeleton of a moderately firm substance, the interstices of which had been filled with the fluid or semi-fluid carrier of the colouring matter; this coloured substance exudes, when heated in the manner described, in the form of green drops. If, however, a dilute acid has been employed, the appearance is different from that produced by moist heat, the drops being then of a firmer consistence and of a rusty brown colour. These brown masses gradually assume an angular crystalline appearance, constituting the substance to which Pringsheim has given the name of hypochlorin. The mode in which it can be obtained shows that hypochlorin is probably decomposed by heat. It evidently exists in the chlorophyll-grains in its natural condition, in addition to the green colouring matter. Were it a product of the action of the acid on the colouring matter, it would make its appearance equally in all the chlorophyll-grains, which is not the case.

Professor Pringsheim has paid especial attention to the effects of intense light on the different constituents of the cell.

The green colour disappears in the course of a few minutes; but this takes place only when oxygen is present, and not in red light. The resulting substances could not be detected, and are therefore probably gaseous, the products of combustion. The author believes, however, that it is rather a pathological than a normal process in the cell. Other yellow, blue, and red colouring matters undergo the same changes as that of chlorophyll; but this is by no means the case with all.

The colourless matrix of the chlorophyll-grains and the substances enclosed in it are adapted for the double function of the grains, the promotion both of assimilation and of respiration. Among the substances thus enclosed are starch, oil, and especially

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[*] 'Nature,' xxiii. (1881) pp. 178–81. Pop. Sci. Rev., v. (1881) pp. 71–7. In full in Journ. Linn. Soc. (Bot.), xviii. (1881), pp. 406–19 (2 figs.).

[†] Jahrb. wiss. Bot., xii. (1881) pp 288–429 (16 pls.).

[‡] See this Journal, iii. (1880) pp. 117, 480.

tannin; but starch is by no means universally present. The starch is not destroyed by intense white sunshine or oxygen.

The hypochlorin is the substance first destroyed by the action of intense light, and its disappearance is the first sign of an injurious influence on the cell.

The protoplasm of the cell undergoes a change under the action of intense light, as is shown by its loss of turgidity, the parietal protoplasmic layer becoming more permeable to the cell-sap. The rotation of the protoplasm is arrested by exposure to strong light; but it will recommence if the exposure has not been too long.

The cell-wall undergoes no material change from exposure to strong light.

The general conclusions to which the investigations of Professor Pringsheim have led him are: (1) That the destruction of the colouring matter of the chlorophyll, even in the living cell, is a process of oxidation, independent of the presence of carbonic acid; (2) That its decomposition in light does not take place in a mixture of carbonic acid and hydrogen of any given proportion, in which assimilation and decomposition of the carbonic acid is possible; (3) that the decomposition of the colouring matter in the living plant is a pathological process; and that, when once destroyed, it cannot be reproduced. He therefore still maintains his previous view that the process of respiration is checked rather than promoted by the presence of chlorophyll, which acts by the absorption of light, favouring at the same time the process of assimilation. The first product of assimilation he believes to be hypochlorin; other substances which are found in the chlorophyll-grain, such as starch, glucose, oil, and tannin, being formed from it by oxidation. The facts upon which Professor Pringsheim rests this conclusion are: that hypochlorin is generally present in chlorophyll-grains; that the amount of hypochlorin in a chlorophyll-grain varies inversely in proportion to the amount of starch; and the further fact that no hypochlorin can be detected in seedlings until their exposure to light has been sufficient to enable them to assimilate.

Transpiration.*—A series of investigations by P. Sorauer on this subject have been directed chiefly to the following points:—The influence on transpiration of temperature; the influence of light; the influence of the particular variety; the relation to transpiration of the fresh weight of the plant; the relation of surface; the relation of the amount of water in the soil; the influence of the moisture of the air; of the size of the root; of manuring; of the partial removal of the leaves; the transpiration of etiolated plants; transpiration in the absence of carbonic acid.

The general conclusions arrived at are that transpiration is a physiological and not a mechanical process; that is, it cannot be compared to a similar process in dead substances. It depends on the

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* Sorauer, P., "Studien üb. Verdunstung." Mittheil. d. pflanzenphys. Vers.-Stat. am K. Pom. Inst. Proskau, iii. (1880) pp. 351–490.

constitution of the plant, which is manifested by the quantity and quality of the dry substance. All external factors which appear to exercise a direct influence on transpiration, affect the quantity, distribution, and composition of the dry substance, and transpiration only indirectly through these. The most important factor in transpiration is light; and the transpiration which takes place by night is a secondary result of the light during the previous day, as is shown by the fact that the amount of transpiration is often greater during the night than during a similar period in the following morning.

Formation of Starch-grains.*—Professor A. F. W. Schimper publishes the results of an important series of observations on the mode of formation of starch within the chlorophyll-grains. Under ordinary circumstances, the starch-grain is formed in all portions of the chlorophyll-grain. This is the case in the mesophyll of the leaf, and also in the green parts of the stem of some, but not of all, flowering plants. But in the stem of many plants the starch-grains are formed in a different way to this, viz. only immediately beneath the surface of the chlorophyll-grain, from which they escape by breaking through the thin layer that overlays them. When the chlorophyll-grains are spherical or flattened, these starch-grains are formed in all parts of the periphery; but when the former are disk-shaped, the localization is carried still farther, and the formation of starch-grains is confined to their equatorial zone.

A difference in the structure of the starch-grains is intimately associated with the locality of their formation. Those produced in the interior of chlorophyll-grains, and entirely surrounded by the chlorophyll, as in the parenchyma of the cortex and pith of *Cereus speciosissimus*, have a centric structure, but usually remain very small; while those formed near the periphery are much larger, and eccentric in their structure, the side which grows most rapidly being the one immersed in the chlorophyll; and the unequal growth is therefore evidently due to unequal nutrition. This is well exemplified in the starch-grains formed in the stems of many plants.

In those parts of the plant which contain starch but no chlorophyll, the grains are not surrounded by ordinary protoplasm, but are enclosed in peculiar strongly refractive particles, usually of spherical or fusiform shape, which are remarkably unstable, disappearing as soon as fluid enters the cell. These particles are produced before the starch-grains, and these latter are formed within them either in all parts or near the periphery only, and their structure then varies in precisely the same way as that of those formed within chlorophyll-grains; the former are centric, the latter eccentric. These albuminous particles are unquestionably the organs for the formation of starch in those cells which do not assimilate, that is, they transform into starch the assimilated substances conveyed to them from other parts of the plant, and may hence be termed *starch-producers* (Stärkebildner). The development of these starch-producers, and of the starch-grains within

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* Bot. Ztg., xxxviii. (1880) pp. 881–902 (1 pl.).

them, is described in detail in the paper in a number of different plants. They can be classified under the following heads:—

- A.—Starch-producers spherical.
    - *a.* They are formed only in the protoplasm which surrounds the nucleus.
        - *α.* They produce starch-grains in their entire mass (*Colocasia*).
        - *β.* They produce starch-grains only in their peripheral portion (*Philodendron, Amomum*).
    - *b.* They are formed in the protoplasm which surrounds the nucleus, and sparingly also in the rest.
        - *α.* They produce starch-grains in their entire mass (*Beta trigyna*).
    - *c.* They are formed in the whole of the parietal protoplasm, and not specially in the region of the nucleus.
        - *α.* They produce starch-grains in their entire mass (*Melandryum*).
- B.—Starch-producers fusiform.
    - *a.* They are formed only in the protoplasm which surrounds the nucleus.
        - *β.* They produce starch-grains only in their peripheral portion (*Phajus*).
    - *c.* They are formed in the entire parietal protoplasm, and not specially in the region of the nucleus.
        - *α.* They produce starch-grains in their entire mass (*Melandryum*).
- C.—Starch-producers at first spherical, afterwards elongated.
    - *a.* They are formed only in the protoplasm which surrounds the nucleus.
        - *β.* They produce starch-grains only in their peripheral portion (*Canna gigantea*).

A comparison of these starch-producers with chlorophyll-grains reveals a very strong similarity between them. They appear to be identical with the leucophyll-grains, especially those in the deeper cells of etiolated stems, where they are perfectly colourless and very evanescent. The mode of formation of the three structures is very similar. Further than this, starch-producers can, under the influence of light, be transformed into chlorophyll-grains. This transformation may take place normally in the course of development of an organ which has, when young, been excluded from the light by being buried in the soil or concealed beneath a thick covering of leaves, and then exposed to light, as the leaves of *Iris*, tubers of *Phajus grandifolius*, &c. Parts abnormally exposed to light, as potato-tubers, form in the same way false chlorophyll-grains from their starch-producers. It is not, however, all starch-producers that are capable of being thus converted into chlorophyll-grains. It may, in fact, be assumed as a general law that leucophyll-grains, etiolin-grains, and starch-producers are nothing else than the young colourless condition of chlorophyll-grains.

The starch is not formed directly by the combination of water and carbonic acid; there are, on the contrary, manifestly a number of little-known intermediate products.

The general results of these observations may be stated to be that there is no such great gap as has hitherto been supposed between the formation of starch in those cells that do and in those that do not assimilate. In those cells that do not contain chlorophyll, there are special structures which produce starch, these being simply immature chlorophyll-grains, which are usually transformed into chlorophyll under the influence of light. On the other hand, chlorophyll-grains are not mere organs of assimilation; in the conducting tissues and receptacles for reserve materials they exercise the same functions as the starch-producers do in the cells that do not assimilate, i. e. they construct starch out of the assimilated substances conveyed to them from other parts of the plant.

Action of Frost on Evergreen Plants.*—When plant-tissues are attacked by frost, ice is generally formed, not in the interior of the cells, but on the surfaces of the organs, or in the intercellular spaces, where indeed considerable quantities of ice may accumulate, forcing back the tissue. When the ice-crystals form in the intercellular spaces of green plants, a change of colour is generally observed; in place of the normal, more or less greyish, green, the parts become much darker green, because the air between the green cells is replaced by ice. These parts are also more transparent than usual.

In frozen leaves these changes may easily be observed, especially on the under sides, where the intercellular spaces are very numerous. The leaves then look as if they were injected with water, and as if water had been introduced into them from without; but really it is the cells that have furnished the water to form the ice-crystals in those intercellular spaces. Thus the case is not one of injection, but of a phenomenon which we might designate as infiltration. If the infiltrated parts thaw, and continue to live, the liquid goes back from the intercellular spaces into the cells, and the normal colour returns.

Besides this infiltration, it may be observed that in various plants in the frozen state their leaves hang down, as if they were withered. On thawing, they resume their normal position. In some few plants both of these symptoms of the frozen state of leaves very quickly disappear, and the idea was suggested that both phenomena are results of very special peculiarities of organization. Still, the possibility remained that they are simply consequences of general, but still little-known, laws, which govern the freezing and thawing of plant-tissues (a matter to be determined only by more extensive systematic research).

This question has been investigated recently by Herr Moll, of Utrecht. He had repeatedly noticed that, by merely touching for a moment, with the finger, the infiltrated leaves of evergreen plants,

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* Naturforscher, xiv. (1881). See Engl. Mech., xxxiii. (1881) pp. 7-8.

he could make the dark-green colour of the lower side give way to the normal colour, while the untouched parts remained infiltrated. This observation prompted some experiments as to whether the infiltration always disappeared with such remarkable rapidity on the thawing of frozen leaves. Accordingly, infiltrated leaves of various plants were plucked, and brought directly into an unheated room, the temperature of which was above zero, and the time in which the dark-green colour was replaced by the normal was observed. In many cases, this took place almost instantaneously, in others the time was longer, but always a few minutes sufficed for all traces of infiltration to disappear, without the plant ever suffering through the rapidity of the thawing. This phenomenon was general.

A further question was, whether in this thawing, when the infiltration suddenly disappears, a rarefaction of air takes place in the intercellular spaces, while the liquid returns into the cells. An affirmative answer would prove that the leaves in freezing underwent a diminution of volume, since the cells let out a part of their sap into the intercellular spaces, and this forced out the air. To ascertain the truth, Moll let the frozen leaves thaw under water, and found that, after thawing, they were, indeed, more or less strongly injected, and so that they had taken up water, becoming more or less darkly coloured in consequence. He inferred that the frozen leaves, on thawing, experience rarefaction of air in the intercellular spaces, and therefore that the freezing is accompanied by a decrease of volume of the leaves.

The visible hanging down of the frozen leaves in many plants formed the subject of a special inquiry, in which he made exact measurements of the direction of the leaves during the process of thawing. With a very simple apparatus, which served to measure the fixation of the leaf on the petiole, and the direction of the leaf-point, Moll satisfied himself that evergreen plants always change their direction in freezing, even where this change is not visible without special means of observation. The time taken by the leaves in thawing to reach their highest position varied in different plants between seven and thirty minutes. On an average it was about eighteen minutes.

As to the rapidity of motion of the leaves, the experiments proved that this at first increases, reaches a maximum, then decreases. The increase, however, lasts but a short time, and the decrease is much longer. Hence the maximum lies not in the middle, but more towards the beginning, and it lasts only a very short time.

Finally, Moll sought to ascertain whether the change of direction of the leaves merely depended on their becoming more lax, or whether other factors operated. In the former case leaves allowed to freeze in an inverted position must equally sink down, and in thawing, they must become erect, but thereby perform a movement which, under normal conditions, would be a sinking. Experiment showed that the laxity of the leaves, whose cells have given up water in freezing, is, if not the only, yet the principal, cause of the down-hanging of frozen leaves.

Insects and the Fertilization of Heterostylous Flowers.*—*Primula elatior* is the plant selected by J. MacLeod for his observations. Here the anthers of the longistyle flowers, which are at the same level as the stigmata of the brevistyle ones, are placed a little above the extremities of the sepals, and in consequence, at some distance from the mouth of the corolla; those of the brevistyle flowers and the stigmata of the longistyle ones are very near this mouth. These arrangements are utilized by the fertilizing insects, two species of *Bombus*, in two different ways. The one *Bombus* (sp. ?) grasps the corolla with its feet, and inserts its head, but not beyond the mouth of the corolla; in order to reach the nectaries at the bottom of the tube, it unrolls its proboscis. Thus, on coming to a brevistyle flower, its head comes into contact with the anthers and carries off pollen from them; but the proboscis, which is projected beyond, does not touch them at all. The same result, substituting stigma for anthers, takes place with a longistyle flower, and pollen is deposited from the bee's head on the stigma, while pollen belonging to the flower itself is carried off by the *proboscis* in this case, to be deposited on the stigma of the next *brevistyle* flower which it sucks.

The other *Bombus* (*B. muscorum*) acts very differently; it grasps the side of the flower and pierces it laterally with its mandibles. Only fully-blown flowers are observed to be thus pierced, and the perforation is always effected at the same level, namely, that of the stigma of the short pistil or the anther of the short stamen (according as it is a brevistyle or longistyle flower). The head is pushed into the opening thus made, and the proboscis is directed towards the nectaries; thus no part of the head or proboscis touches the long stigma or anthers, and it is only brevistyle flowers which are fertilized by this species of bee. Thus, as far as the agency of the *Bombi* is concerned, the brevistyle flowers have two chances of fertilization to one which the longistyle flowers possess, seeing that the latter can be fertilized by but one of the two species of bee; if these insects were the only ones which fertilize these flowers, it seems probable that natural selection would favour the brevistyle flowers in the struggle for existence, at the expense of those with long styles.

Contrivances for Insect-pollination in Erodium.†—F. Ludwig points out that, besides the ordinary form of *Erodium cicutarium*, there is another, var. *pimpinellifolium* Willd., especially adapted for cross-fertilization by insects. In the ordinary form the petals are all coloured uniformly, the upper shorter ones having only occasionally a deeper tint; while in this variety the two upper petals are shorter, broader, and of a much deeper red, with an oval dark spot at the base. This form is also distinctly proterandrous, and the position of the stamens prevents insects entering the flower while the pollen is being discharged and before the stigmas are mature; while the original form is homogamous or slightly proterogynous, and to all pp earance autogamous.

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* Bull. Acad. Roy. Belg., l. (1880) pp. 27–33.

† Kosmos, viii. (1881). See Bot. Centralbl., ii. (1881) p. 298.

The ordinary form of *E. moschatum* corresponds to the original autogamous form of *E. cicutarium*, while *E. macrodenum* appears to be a form of *E. moschatum* corresponding to the var. *pimpinellifolium* of *cicutarium*, in which autogamy is absolutely prevented; the ordinary *E. moschatum* is autogamous and homogamous, or slightly proterogynous. *E. gruinum* has only one form, with handsome nectariferous flowers, proterogynous and xenogamous.

Lime in Plant Life.*—Stohmann has shown the necessity of lime for the development of plants; but its function has not been fully made out. Böhm has shown that lime is necessary, in the earliest stages of plant life, for the consumption of the non-nitrogenous reserve-material; he also concluded that lime was as necessary to the building-up of plant-structure as to the change of cartilage into bone. From the rapid absorption of lime by sprouting bulbs, and the simultaneous appearance of calcium oxalate, Kellermann supposed that lime might act on the solution of the starch by the formation of a ferment.

The experiments on bean plants, detailed in a paper by E. v. Raumer and C. Kellermann, were conducted by Raumer. Some of the plants were grown in acid-washed quartz-sand, and fed with different solutions, both free from and containing calcium salt; the plants produced were examined macroscopically only. The results agree essentially with those of Böhm and others, and show specially that the function of the lime is closely connected with the consumption of carbohydrate; further, the amount of lime present in the seed is not sufficient for the use of the non-nitrogenous reserve-material. Whether the lime acts in the dissolving and transport of the reserve starch, or in the decomposition of the starch to form cellulose, is a difficult question to answer, but the weight of evidence is in favour of the latter view.

B. CRYPTOGAMIA.

Classification of Thallophytes.†—In Professor Cohn's latest system of classification of Thallophytes, he first divides them into two natural series, Carposporeæ and Gamosporeæ, which diverge from the same point of departure, touching one another in their lowest members.

I. Carposporeæ.—Reproduction by spores, which in the typical families are formed in differentiated fructifications, produced either non-sexually as shoots from the thallus, or sexually as the development of a fertilized reproductive cell (carpogonium). No ciliated zoogonidia. Thallus, as a rule, formed from a weft of rows of cells (filaments or hyphæ).

1. *Schizosporeæ.* Cells free, or united into rows or colonies; no fructification; reproduction by cells (germinal cells) or rows of cells (germinating filaments), which are isolated by fission, or by resting cells (spores). *a.* Schizophyteæ. Cell-contents coloured by phyco-

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* Landw. Versuchs-Stat., xxv. (1880) pp. 25-38. See Journ. Chem. Soc., Abstr. xxxviii. (1880) p. 568.

† JB. schles. Ges. vaterl. Cultur, 1879, pp. 279-89. See Bot. Centralbl., ii. (1881) p. 321.

chrome:—Chroococcaceæ, Oscillariaceæ, Scytonemaceæ, Nostocaceæ, Rivulariaceæ. *b.* Schizomycetes. Cell-contents without phycochrome:—Micrococcaceæ, Bacillaceæ, Cladotrichaceæ, Myconostaceæ.

2. *Tetradosporeæ* (Florideæ). Thallus usually a weft of cells; the cellular structure resulting from the fertilization of a carpogonium by non-ciliated spermatozoids (spermatia), formed in sporangia by the budding or fission of rows of cells. Non-sexual reproductive cells formed in tetrads. Cell-contents coloured by phycochrome or rhodophyll, rarely by phycophæin (Dictyotaceæ):—Bangiaceæ, Dictyotaceæ, Nemaliaceæ, Lemaneaceæ. Ceramiaceæ, Gigartinaceæ, Sphærococcaceæ, Rhodomelaceæ.

3. *Ascosporeæ.* Thallus, as a rule, woven into a mycelium; fructification produced non-sexually or by budding from the carpogonium: fertilization by means of spermatia or pollinodia; spores produced in asci by free cell-formation or apparent transverse septation; non-sexual reproduction by means of abstricted germinal cells or conidia; cell-contents without chlorophyll. *a.* Gymnocarpi. Asci single, collected into balls or a layer, without forming a fructification; spores produced by free cell-formation:—Saccharomyces, Ascomyces, Exoascus, Gymnoascus. *b.* Æcidiocarpi. Fructification with asci which break up by transverse septation into rows of cells:—Uredineæ, Calyciaceæ. *c.* Discocarpi. Fertilization open when mature; the spores, developed in the asci by free cell-formation, formed on an expanded layer:—Stictideæ, Graphideæ, Hysteriaceæ, Bulgariaceæ, Lecideaceæ, Pezizaceæ, Collemaceæ, Parmeliaceæ, Usneaceæ. *d.* Porocarpi. Perithecium with an open pore, through which the spores pass when they escape from the asci:—Laboulbeniaceæ, Sphæriaceæ, Lichinaceæ, Verrucariaceæ, Pertusariaceæ. *e.* Cleistocarpi. Perithecium closed, the spores escaping only by its decay:—Erysiphaceæ, Eurotiaceæ, Tuberaceæ.

4. *Basidiosporeæ.* Thallus woven into a mycelium; fructification produced non-sexually (or by the fertilization of a carpogonium?) from the thallus; spores abstricted from basidia; cell-contents without chlorophyll:—Auriculariaceæ, Tremellaceæ, Hymenomycetes (including Telephoraceæ, Clavariaceæ, Polyporaceæ, and Agaricaceæ), Gasteromycetes (including Phallaceæ, Hymenogastraceæ, Lycoperdaceæ, and Nidulariaceæ).

II. GAMOSPOREÆ. Cells free, in families, or united into families or plates, or into a tissue. Reproduction by spores, produced from the entire protoplasm or a portion of it, of all the cells of the thallus, or of only certain cells (in the Fucaceæ only in definite regions of the thallus, the fertile region), directly, or after previous coalescence with a similar or with a sexually differentiated primordial cell, and developing into a new organism. The union of the copulating cells, on a favourable condition for it, is effected by spontaneous motion, usually by means of swarm-cells or zoogonidia. Cell-contents either with or without chlorophyll.

1. *Conjugatæ.* No zoogonidia; sexual reproduction by zygospores; cells free or united into families (colonies or filaments), or interwoven into a mycelium. *a.* Zygophyceæ:—Bacillariaceæ, Desmi-

diaceæ, Zygnemaceæ. *b.* Zygomycetes, Entomophthoraceæ, Ustilaginaceæ, Piptocephalideæ, Mucoraceæ.

2. *Siphoïdeæ.* Cells asciform, differentiated into radicular, axial, and fertile regions; non-sexual reproduction by zoogonidia, sexual reproduction by the union of similar motionless (Zygosporeæ) or swarm-cells, gametes (Syngametæ), or by the union of a swarm-cell (spermatozoid) with a motionless primordial cell or ovum (Oosporeæ). *a.* Siphophyceæ:—Caulerpaceæ, Bryopsideæ (Botrydium), Codiaceæ, Vaucheriaceæ (the latter family only belonging to the Oosporeæ, the rest to the Syngametæ). *b.* Siphomycetes:—Peronosporaceæ, Saprolegniaceæ, Chytridiaceæ.

3. *Cœnobiæ.* Cells undifferentiated into regions, free or united into families (colonies); reproduction as in (2). *a.* Cœnophyceæ:—Protococcaceæ, Palmellaceæ, Valoniaceæ, Volvocaceæ, Hydrodictyaceæ. *b.* Cœnomycetes:—Myxomycetes.

4. *Confervoïdeæ.* Rows of cells simple (monostichia), or often branched, rarely in plates; reproductive cells developed in all or only in certain members of the filaments. *a.* Syngametæ:—Ulvaceæ, Ulotrichaceæ, Cladophoraceæ. *b.* Oosporeæ:—Sphæropleaceæ, Œdogoniaceæ, Coleochætaceæ.

5. *Fucoïdeæ.* Cells united, in the typical forms, into a parenchymatous tissue; reproductive cells produced in receptacles (sporangia), which are limited to definite regions of the thallus (fertile region). *a.* Phæosporeæ (Syngametæ):—Ectocarpeæ, Sphacelariaceæ, Chordariaceæ, Laminariaceæ, Sporochnoideæ. *b.* Oosporeæ:—Fucaceæ.

The Characeæ are placed by the author among the Bryophyta, since the "oospore" of that family must be regarded as a monosporous sporogonium. He terms them *Phycobrya*, forming the first order of Bryophyta, and constituting a state of transition to the second order, the Musci, which must be divided into a large number of equivalent families.

Muscineæ.

European Harpidia.[*]—Dr. C. Sanio gives a complete synopsis of the section "Harpidium" of *Hypnum*, characterized, in addition to structural peculiarities, by growing in water or damp meadows or bogs. The following are the characters used in the sub-sections. I. Species quarum folia cellulis alaribus manifestis plerumque numerosis instructa sunt. *a.* Species monoicæ. 1. *Hypnum uncinatum;* 2. *H. fluitans* (cum varietatibus); *b.* Species dioicæ; 3. *H. exannulatum* (cum varietatibus); 4. *H. aduncum* (cum varietatibus numerosis); 5. *H. scorpioides.* II. Species cellulis alaribus nullis vel raro paucis obsoletis. *a.* Species monoica. 6. *H. revolvens; b.* Species dioicæ; 7. *H. intermedium;* 8. *H. lycopodioides* (cum varietatibus).

Fungi.

Hymenomycete with the Hymenium on the under side.[†]—In addition to his previous record of this abnormal structure,[‡] S. Schulzer

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[*] Bot. Centralbl., i. (1880) Gratis-Beilage ii.

[†] Oesterr. Bot. Zeit., xxxi. (1881) pp. 113–15.

[‡] See this Journal, ii. (1879) p. 314.

now describes a second in the case of *Merulius lacrymans.* Of this polymorphic fungus he describes five distinct forms, giving to the one in question the name *obverse-polyporoides*, which was observed in one locality only. In a pileus of ordinary structure the hymenium disappeared from the under side, and then from its upper and under sides and margin sprang other small ones horizontally. From these there separated after a time from the convex upper side a delicate pellicle or *velum partiale*, exposing minute tubes, the concave under side remaining sterile. Only a *hymenium spurium* occurs. The apices of the hyphæ, from which the tubes are constructed, project slightly into the cavity and produce ovo-spherical spores, 3-4 μ long, which are at first hyaline, and afterwards slightly coloured. The flesh has a somewhat unpleasant tinder-like odour. All the parts are at first white, becoming subsequently brownish-yellow or brown. There is no exudation of drops of water.

Gymnoascaceæ.*—In an account by Eidam of a new series of investigations into the structure of this small family of Ascomycetes, he states their common distinguishing character to be the absence or only defective presence of a true enclosed fructification, the asci being nearly or completely exposed, whether they are solitary or arranged in groups, or on a dense hymenium. From the family he eliminates the genera *Endomyces*, *Saccharomyces*, and *Protomyces;* considering the second of these to belong more properly to the Phycomycetes near the Mucorini, and the last to be more nearly allied to the Chytridiaceæ. The genera which properly belong to the family he classifies as under:—

I. Parasites; living in the tissue of leaves and fruits.
    1. *Ascomyces.* No mycelium: asci 8-spored.
    2. *Taphrina.* Mycelium rudimentary: asci many-spored.
    3. *Exoascus.* Mycelium much-branched and septated; asci naked on a simple hymenium.

II. Saprophytes: with large mycelium.
    4. *Ascodesmis.* Hymenium dense, bearing the paraphyses and asci; envelope completely wanting.
    5. *Gymnoascus.* Asci formed in aggregations of the mycelium, which clothes the asci with a loose and interrupted envelope.

With regard to the systematic position of the family, the four first genera show an affinity to the Discomycetes, the fifth to the Pyrenomycetes.

The author follows out the development of *Ascodesmis* and of *Gymnoascus Reessii.* In the latter he differs somewhat from the account given by Baranetzky. On a segmented mycelial filament is formed a lateral branch, which winds spirally round the next adjacent cell of the mother-filament, becoming closely attached to it, and sometimes embracing also another neighbouring mycelial filament in the same way. The cell which is thus enveloped then breaks up into

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* Cohn's Beitr. Biol. Pflanzen, iii. (1880) pp. 267-301.

two or three daughter-cells, one of which remains sterile, while the others put out slender branches. According to the vigour of the individual one or more branches of the spirally coiled filaments are able to develope asci.

The author then describes in detail the structure and development of *Ctenomyces serratus*, representing a new genus of the family, which sprang from a moist bird's feather. On the quill was found a sclerotium-like resting mycelium distinguished by numerous comb- and hook-like projections, consisting of from eight to ten cells, each of which put out, and always on the same side, a more or less curved appendage, which gave the peculiar comb- or rake-like appearance to the whole structure. From this mycelium there grew upwards a delicate hyphal web, which produced first conidia and subsequently asci. The conidia vary in form. In the simplest form long branches of the mycelium produce the conidia on short erect pedicels, sometimes directly, sometimes on short lateral branches. They are club-shaped, 1 or 2-celled, 5·5 to 6·5 μ long, and 2–3 μ broad. In other cases a smaller or larger number of conidiophores are congregated into a tuft, and each of them is usually branched abundantly and in an extremely regular and beautiful manner. The branches spring one generation from another almost exactly at a right angle. Thirdly there are agglomerations of conidia which closely resemble the bundle of asci. These occur only in feeble specimens. The ascus-aggregations of *Ctenomyces* are spherical or ovoid, 0·5–1·5 mm. in diameter, and consist of a dense, broad, colourless envelope closed on all sides, and composed of numerous loosely interwoven hyphæ. The hyphæ are sometimes torulose and composed of roundish or top-shaped cells, sometimes furnished only on one side with lumps and teeth, but displaying in both cases a beautiful structure. The ends of the hyphal branches are often elongated into long, slender threads which are coiled in a very regular manner. The envelope or pericarp attains a thickness of 50–80 μ, and encloses the outermost bundle, which is composed of densely packed asci rendered polygonal by pressure.

The development of the aggregation takes place as follows:—Its first rudiment appears in the form of a short branch which somewhat swells out above, and is embraced by a hypha, originating either from the same or from a neighbouring mycelial hypha. This hypha coils more and more firmly, in from 1 to 8 spirals, round the club-shaped branch which grows only slightly in length. The spiral hypha has now a number of septa, and each of the cells thus formed increases in length, and the coils thus become broader, and often stand in great curved lines away from the club-shaped branch. Branches then shoot from them, the lowermost serving as organs of attachment, the rest producing tufts of asci. The club-shaped branch in the middle of the ball has in the meantime divided into three cells, of which the uppermost is nearly empty and may be compared to the sterile cell of *Gymnoascus*. The envelope or pericarp originates from the mycelium, a great number of the hyphæ branching copiously around the ball while it is still young. Most of these branches then stand out on one side and are curved, gradually assuming a horn-like appearance, which, however, disappears with the further development of the ball; the hyphæ continue to develope, taking the form characteristic of the genus, torulose or comb- or saw-shaped, the terminal branches appearing as if coiled like a corkscrew. The spores are in the meantime developed within the asci, which are apparently unstalked, almost globular, 4–5 μ in diameter; the spores being about 2 μ long, and 0·9–1·1 μ broad, nearly cylindrical in form and 8 in an ascus. The diagnosis of *Ctenomyces* is thus given:—Pericarp of the ascus-conglomeration not cuticularized, closed on all sides, colourless or very pale yellow, composed of an interwoven, loosely stratified comb- or bead-like web of hyphæ permeated by numerous air-cavities, but most resembling the perithecium of the higher Ascomycetes, and especially of the Gymnoascaceæ. The conglomeration originates from two hyphæ, the one a club-shaped mycelial filament, the other a coiled ascogenous spiral; each is almost always surrounded by its own pericarp. The asci and ascospores are very small and delicate, all of the latter in the same ball always ripening simultaneously. Conidia upon simple conidiophores, formed singly, or in groups, or in closed conidial agglomerations.

The author next describes in detail the development of a new species of *Gymnoascus*, *G. uncinatus*, found on the droppings of sparrows. It consists of roundish hyphal agglomerations, covered on the outside with numerous long, beautifully curved branches. The course of development is essentially the same as in *G. Reessii*. The asci are ovoid or pear-shaped, with a diameter of 8·5–9 μ; the spores spherical or somewhat ovoid, orange-coloured, and about 3·5 μ in length.

The author considers that this peculiar and complicated structure points unmistakably to the origin of the asci of the Gymnoascaceæ from a yet undiscovered act of impregnation.

Glœosporium reticulatum Mt. in France.*—This parasite made its appearance on melons in the neighbourhood of Châlons-sur-Marne in August 1880, during cold, rainy weather, spreading until it had destroyed about half the crop. The layers of spores are gelatinous, arranged in regular circles, coalescent, and from 1·5 to 6 cm. in diameter; the basidia are short, densely crowded, unbranched, 15-20 μ long, and 3–5 μ thick; the spores are fusiform, curved, colourless, unicellular, 16–18 μ long, 5–6 μ broad. This fungus was originally described by Montagne as a *Fusarium*, and by Passerini as *F. lagenarium*; Saccardo considers it a *Glœosporium*.

Blodgettia, a new Genus of Parasitic Fungi.†—Under the name *Blodgettia confervoides*, Harvey described what he considered a new genus of green algæ belonging to the Valoniaceæ, found on rocks near low-water mark at Key West. A close examination of this organism by Dr. E. P. Wright has convinced him that it consists of

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* Rev. Mycol., ii. (1880) pp. 169–72.

† Trans. R. Irish Acad., xxviii. (1881) pp. 21–6 (pl. ii. figs. 1–3).

a *Cladophora*, with a fungus parasitic upon it. For this fungus he retains Harvey's generic name for the entire organism, calling it *Blodgettia Bornetii*, and thus summarizes the characters of genus and species:—

Blodgettia gen. nov. Conidia scarcely cylindrical, moniliform, borne on short peduncles; hyphæ at first free, then occasionally inosculating, only the older portions giving origin to conidia. *B. Bornetii* sp. nov. Conidia two to five in number, the central ones larger than those at base or apex of the string, of a dark brown or brownish-red tinge. Dr. Wright does not attempt to assign any systematic position to the fungus.

"Leaf-brown" of the Bean.*—According to von Thümen, this disease is caused by a parasitic fungus, *Isariopsis griseola* Sacc., which forms small isolated specks on the under side of the leaves of *Phaseolus vulgaris* and *nanus*, of an ashen-grey colour, and usually bounded by the veins, corresponding to brownish-grey ill-defined specks on the upper side. The mycelium is found only beneath these specks. Artificial infection can be very readily brought about. The parasite appears to be spreading from Italy northwards.

Chrysomyxa pyrolata.† — G. Winter confirms Dr. Rostrup's discovery ‡ of a *Chrysomyxa* parasitic upon *Pyrola*, and identifies it with *Uredo pirolata* parasitic upon the same host, but quite distinct from *U. pyrolæ*, which is the conidial form of a *Melampsora* rather than of a *Cæoma*. The *Chrysomyxa* appears on the under side of the leaves of the *Pyrola*, without any formation of specks, in the form of small, dot-like, reddish-yellow, shining spore-layers; the spores put out promycelia with spherical sporidia; the promycelia are multicellular, each cell forms a sterigma with a single sporidium of about 7 μ diameter. The æcidio-form of this *Chrysomyxa* has not yet been recognized.

Ergot.§—In an exhaustive treatise on rust and ergot (*Claviceps purpurea*), A. Renner treats of the literature of the subject; a full description of the sclerotium of the *Claviceps* and of its hosts; its development and the germination of the ascospores; the formation of the sphacelia and of honeydew; the formation and germination of the conidia; and the means for its destruction. The author considers the formation of the sclerotium to be probably due to a process of fertilization. He enumerates thirty-one species of grass on which the ergot is parasitic.

Fungoid Diseases of Animals.‖—In an account of the diseases due to fungi which attack animals, O. Bollinger states that the lowest animals, the Protozoa, appear to be exempt from their attacks. In

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* Oester. Landw. Wochenbl., vi. (1880) p. 312. See Bot. Centralbl., ii. (1881) p. 242.

† Bot. Centralbl. ii. (1881) p. 250.

‡ See this Journal, *ante*, p. 282.

§ Renner, A., 'Der Brand u. das Mutterkorn u.s.w.' (Magyar) (22 pls.), Budapest, 1880.

‖ Bollinger, O., 'Ueber Pilzkrankheiten niederer u. höherer Thiere, München, 1881. See Bot. Centralbl., ii. (1881) p. 274.

the hard parts of the Cœlenterata, Annelida, and Cirripedia, and in the shells of the Acephalæ, Brachiopoda, and Gasteropoda, the mycelia of fungi have been detected; while among Vermes, *Ascaris mystax* alone is known as the host of *Mucor helminthophthorus*, which closely resembles the *M. melitophthorus* found in the abdomen of bees. Of fungi parasitic on insects there are a large number; those which attack silkworms having been especially a subject of investigation. Of these there are three: (1) the "pébrine" or "gattine," caused by a bacterium, *Nosema bombycis*, which may be derived from the external air, from the food, or through the eggs; the best means for preventing its spread is the microscopic examination of the female moth; (2) the "Schlafsucht" or "flacherie," not yet accurately investigated, but undoubtedly due to a bacterium; and (3) the "muscardine," *Botrytis Bassiana*, the spores of which, carried through the air, settle on the body of the larva, put out their germinating tubes, penetrate the uninjured skin, and produce within the body first conidia and then a mycelium, causing death in from twelve to fourteen days.

An allied parasite, *Cordiceps militaris*, is also very destructive to the larvæ of insects, and another attacks the cochineal insect. The *Empusa* which so abundantly attacks flies, &c., is treated in detail.

As regards Vertebrata, the author describes only the "mycosis" of fishes and birds; with a few remarks on the fungi parasitic on eggs. Of dermatomycoses, he speaks only of the "favus" of birds. There are also bacteria which cause diseases of the valves and muscles of the heart, of the lungs, liver, &c. The author regards the epidemic as a powerful support, from an etiological point of view, of the theory of contagium vivum. In the mycosis of the lower animals all the characteristics of the epidemic of man and the higher animals can be demonstrated:—the incubation, the normal course, and the mode in which the infectious substance can enter and spread in the body. The resemblances and differences of the various kinds of infectious diseases due to the attacks of fungi are discussed in detail.

Magnin's Bacteria.*—Dr. A. Magnin's work on the Bacteria has been translated into English by Dr. G. M. Sternberg, Surgeon U.S. Army, and will be very welcome to many observers as a convenient résumé of our knowledge (still only very incomplete) of these forms carried down to a recent date.

The book is divided into two parts—Morphology and Physiology. Under the former head the form, movements, structure, and different modes of association of the Bacteria are dealt with, together with their classification (that of Cohn being given in full), with twenty-four pages of "descriptions of genera and species." The Physiological part comprises the origin of bacteria, their nutrition, respiration, and reproduction, together with their *rôle* in fermentations,

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* Magnin, A., 'The Bacteria.' Transl. by G. M. Sternberg, M.D. (8vo. Boston, 1880.) 227 pp. (10 pls.).

putrefactions, and nitrification, in contagious diseases and virulent infections, and in surgical lesions. The author thus sums up "the actual state of our knowledge upon the Bacteria:—

1. The Bacteria are cellular organisms of vegetable nature.

2. Their organism is more complicated than was for a long time believed. The principal points brought to light are: their structure, the presence of cilia, the nature of the substances contained in their protoplasm, coloured granules, grains of sulphur, &c.

3. The forms of *torula*, *zooglœa*, *leptothrix*, *mycoderma*, &c.

4. The multiple affinities of the Bacteria, on the one hand with the algæ, on the other with the fungi, differently understood by authors, and their development, still unknown for the greater number of species, make it impossible to classify these beings except in a provisional manner.

5. This development, well studied in several species of *Bacillus*, has proved that bacteria may multiply not only by fission, but also by formation of spores, and even by veritable sporangia.

6. These spores or permanent germs are the principal means by which these inferior organisms are disseminated.

7. As to their *rôle* in fermentations, in putrefactions, in contagious diseases, and in surgical lesions, notwithstanding the considerable number of labours of which the Bacteria have been the object in these different points of view, it is not yet possible to define it in a certain manner."

In concluding the historical part of the book, the author adds that "in presence of these opinions, so diverse, as to the nature of the Bacteria and their classification, we will finish by saying with Cohn:—

"So long as the makers of Microscopes do not place at our disposal much higher powers, and, as far as possible, without immersion, we shall find ourselves, in the domain of the Bacteria, in the situation of a traveller who wanders in an unknown country at the hour of twilight, at the moment when the light of day no longer suffices to enable him clearly to distinguish objects, and when he is conscious that, notwithstanding all his precautions, he is liable to lose his way."

Not the least valuable part of the book is the thirty-two pages of Bibliography, commencing with Leeuwenhoek's 'Opera Omnia,' of 1772, and ending with a list of more than fifty-two papers, published in 1880.

Reproduction of the Bacteria.—The physical teacher, in order to convey to his pupil an idea of distance in the universe, surprises him with calculations of the number of centuries that it would take for a railway train or a cannon ball to traverse the given space. The following calculations, given by Cohn, apply the same idea to a biological question:—

"Let us suppose," says Cohn, "that a bacterium divides into two in the space of an hour, then in four at the end of a second hour, then in eight at the end of three hours, in twenty-four hours the number will already amount to more than sixteen millions and a half

(16,777,220); at the end of two days this bacterium will have multiplied to the incredible number of 281,500,000,000; at the end of three days it will have finished forty-seven trillions; at the end of about a week, a number which can only be represented by fifty-one figures.

In order to render these numbers more comprehensible, let us seek the volume and the weight which may result from the multiplication of a single bacterium. The individuals of the most common species of rod-bacteria present the form of a short cylinder having a diameter of a thousandth of a millimetre and about one five-hundredth of a millimetre in length. Let us represent to ourselves a cubic measure of a millimetre. This measure would contain, according to what we have just said, 633,000,000 of rod-bacteria without leaving any empty space. Now, at the end of twenty-four hours, the bacteria coming from a single rod would occupy the fortieth part of a cubic millimetre; but at the end of the following day they would fill a space equal to 442,570 of these cubes, or about half a litre. Let us admit that the space occupied by the sea is equal to two-thirds of the terrestrial surface, and that its mean depth is a mile, the capacity of the ocean will be 928,000,000 of cubic miles. The multiplication being continued with the same conditions, the bacteria issuing from a single germ would fill the ocean in five days."*

New Coloured Bacterium.†—Like similar discoveries, that of Dr. C. Bergonzini was made accidentally. An open vessel containing a solution of egg-albumen had been left for about a month untouched, and its liquid was then found to have assumed a greenish-yellow colour, and a thick dark violet-coloured pellicle covered the surface.

The colour was due to a bacterium, which, however, differed from the known purple *Chromococcus violaceus* in being insoluble in water; the pellicle consisted of a *Mycoderma*, made up of small violet bacteria, which exhibited decided movements when isolated in the liquid; they were cylindrical, and measured $0 \cdot 6\ \mu$ to $1\ \mu$ in diameter, $2\ \mu$ to $3\ \mu$ in length. Though the colour is insoluble in water, it is readily dissolved by alcohol, which takes a deep blue colour from it, leaving it whitish; ether dissolves out with difficulty a red-violet colouring matter, which is also insoluble in water. The pellicle and the alcoholic solution both become green when treated with hydrochloric acid; nitro-hydrochloric acid alters it to a pale yellow by a process of reduction. Strong caustic potash dissolves out a light red colouring matter. The addition of ammonia to the blue dilute alcoholic solution produces an opalescence, followed by precipitation of greyish-violet flakes. A moderately strong alcoholic solution, 8 mm. thick, examined with the spectroscope, showed complete absorption of the yellow and orange in the spectrum, and a small absorption line between Fraunhofer's C and D. These reactions, and those of the red form, described by Ray

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* Loc. cit., pp. 124–6.

† Annuario Soc. Nat. Modena, xiv. (1880) pp. 149–58.

Lankester as *Bacterium rubescens*, show many points of analogy with those of chlorophyll. Milk appears to be unfitted for the growth of the bacterium. In conclusion, the author argues at some length in favour of the cellular nature of bacteria.

Bacillus of Contagious Molluscum.*—M. Domenico, who has previously upheld the contagious character of this disease, has undertaken experiments of artificial culture to determine the exact nature of the different structures which have been shown by Dr. A. Angelucci to accompany it. The molluscous nodules were kept either in distilled water, or in the moist chamber; the vessels were hermetically sealed, and kept at a temperature of 20°–30° C.

Microscopical examination of such specimens (1) after three hours, showed that the *granules* had multiplied and grown larger, and had altered in appearance from that of micrococci to that of *sporidia*, being very mobile, refringent, and varying in shape; they now form aggregations around the *yellow balls* of the molluscous capsule, among the epithelial cells, and in the lining connective tissue; (2) After six hours' culture the sporidia have become fewer, and are in part replaced by strings, flakes, or more compact masses of *Bacilli*, which surround the yellow balls; they exhibit lively forward or rotating movements when warmed. In twelve hours the masses of sporidia have entirely disappeared; the Bacilli now occur in the capsule and interstitial connective tissue; some of them may be seen united in pairs by an interposed sporidium, and bent at an angle; others bear a sporidium at one end. They exactly resemble figures of *Bacillus lepræ* and *B. malariæ*. (3) In twenty-four hours the naked eye can perceive a whitish zone surrounding the nodules, and threads floating in the cultivating liquid; both appearances are caused by masses of Bacilli, and by zigzag bacillar filaments, among which clusters of sporidia have again appeared. In two days the surface of the liquid is covered with whitish masses of sporidia and bacillar filaments, and hardly any separate Bacilli occur. Thus the "granules" of this disease are not *Micrococci* of Cohn's classification, but are sporidia of a more highly organized species, the *Bacillus mollusci*.

Fungus of Ringworm (Trichophyton tonsurans).†—Dr. G. Thin writes that when hairs affected with the *Trichophyton tonsurans* are cultivated in cells, the development of the spores on the sides of the hairs can, if it occurs, be observed *in situ* under the Microscope. When the attempted cultivation takes place on the surface of a fluid in a test-glass, it is also possible, after maceration in solutions of potash, to decide whether the spores in the hairs have grown out from the surface of the hair, and to distinguish between a growth of adventitious fungi and the growth of the *Trichophyton*.

An account is given of experiments made by the use of cells and test-glasses, which were kept at a temperature of between 92° and 98° F., but in a few instances at the ordinary room temperature. The

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* Atti Accad. Lincei, Transunti, v. (1880) pp. 77–9.

† Proc. Royal Soc., xxxi. (1881) pp. 501–2.

Trichophyton remained sterile in cultivations attempted with a solution of phosphate of soda and tartrate of ammonia, with Cohn's fluid, milk, carrot infusion, turnip infusion, salt solution (0·75 per cent.), egg albumen, egg albumen and potash, and vitreous humour and potash. The only method by which it was grown was by moistening the hairs with vitreous humour. When moistened with vitreous humour, the spores on the sides of the hairs placed in cells were seen to grow into a mycelium, and free growth took place when the hairs were floated on the surface of this fluid in test-tubes. It did not grow in cells when the hairs were immersed in a large drop, nor in test-tubes when the hairs were kept at the bottom of the tube.

The growth observed consisted in a formation of mycelium, which sprouted from the spores in the hairs, and in the formation of spores in the newly-formed mycelium.

It was shown by experiments in which *Aspergillus*, *Penicillium glaucum* and other fungi grew around the hairs, whilst the spores of *Trichophyton* remained sterile, that the latter is essentially distinct from the common fungi whose spores are present in the atmosphere.

The fact that the spores of the *Trichophyton* will not grow when immersed in vitreous humour, whilst they do grow when only moistened by it, explains why inflammatory exudation from the blood-vessels cures ringworm of the scalp.

Absorption of Pigment by Bacteria.*—Dr. Thin, in reference to the fact that certain fungi possess the property of taking up colouring matter from the medium in which they grow, has observed in the *Trichophyton tonsurans* that both in man and in the horse the fungus may acquire a dark colour from absorbed pigment. In the case of the horse, he found the mycelial wall represented by an apparently empty dark tube, and at the same time spores blackened with a coating of pigment.

An analogous appearance exists in bacteria.

The bacteria found in the cultivations referred to in the preceding note are seen in the transition forms of a spore or coccus, an elongating spore, rods, elongated rods, sometimes of great length, long rods, with the first appearance of a differentiation of the protoplasm into sporules, and finally as tubes full of spores or cocci.

These appearances have been followed in several specific organisms, and first of all in *Bacillus anthracis*. They would seem to indicate the ordinary life-history of at least many bacteria. Frequently the preparations contained long bacteria rods which had taken up pigment from the hair. This pigment was often found at one end of a long rod, whilst towards the other end the rod was free from it, and in the part of the rod in which the pigment was found the spore formation could in several instances be seen to be more advanced than at the part which was free from pigment. The pigment was packed in the tubes around and between the spores, but, by focussing, it could be seen that the substance of the spore was free from it. The free spores and short rods were free from pigment. The bacteria in which

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* Proc. Royal Soc., xxxi. (1881) pp. 503–4.

it was observed showed no other peculiarities, and were of about the same calibre as the rod bacteria usually observed.

The fact is noted as affording proof that bacteria can take up minute solid particles through their walls.

Bacterium decalvans.*—Dr. Thin also describes this organism, which is associated with the destruction of the hair in Alopecia areata. Having found bacteria adherent to the roots of extracted hairs, he subjected hairs in six selected cases to processes designed to demonstrate the existence of organisms should they be present in the substance of the diseased hairs. In five out of the six cases, an object was observed in the hairs which he believed was a *Bacterium;* their size and form were the same, and they had the refractive qualities of bacteria.

In seven consecutive cases disease was at once and definitely arrested by a treatment designed to destroy the vitality of any bacteria which might be present on the surface of the skin, and at the same time to present a mechanical obstacle to their progress in growth from one hair-follicle to another.

Mitigation and Renewed Activity of Organized Poisons.†—The application of atmospheric oxygen to the mitigation of the activity of bacterium poisons, already shown to promote this object, is now further dealt with by L. Pasteur, and Messrs. Chamberland and Roux.

The mycelium of anthrax—unlike that of fowl-cholera and the yeast bacterium—becomes resolved, after from twenty-four to forty-eight hours' growth, into spores; these germs undergo no loss of vitality or virulence by exposure to the air, while the mycelium is affected by this process; hence to diminish the virulence of the poison it should be attacked under circumstances which prevent its passing into the spore condition; a temperature not exceeding 16° C., or one between 42° C. and 43° C. furnishes those circumstances, at any rate for considerable periods of time. At the latter temperature the growth dies in a month, and after eight days it has lost its deadly properties; in the same way as the fowl-cholera bacterium, it passes through stages of mitigation of its power until the time when this power is entirely lost; in the same way also the mitigated poison constitutes a vaccine capable of protecting from the disease. On the other hand, it is possible to restore to this poison its full activity; this is effected by inoculating with it a guinea-pig one day old, and transferring its infected blood to a similar animal, and so on; the animals at this age are invariably killed by the mitigated poison, and after this process had been repeated several times, the poison recovers its full vigour, and will kill even sheep. Similarly the mild form of the fowl-cholera poison may be restored to full activity by passing it through those small birds, as sparrows, canaries, &c., to which it is immediately fatal. These considerations furnish an explanation of the so-called *spontaneous* appearance of certain epidemics; thus the plague, which is confined to certain

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* Proc. Royal Soc., xxxi. (1881) pp. 502–3.

† Comptes Rendus, xcii. (1881) pp. 429–35.

countries, undoubtedly lies dormant for certain periods in a mitigated form; and the same is the case with the typhus of camps, which is not thus limited in space; man himself may carry the germs until circumstances, such as climatal conditions, famine, and weakness, give opportunities for their development.

Inoculation a means of protecting Sheep against Charbon.[*]—This fact is admitted by Messrs. L. Pasteur, Chamberland, and Roux, to have been already proved by M. Toussaint,[†] but they dispute some of his opinions and facts relating to the subject. Thus his view that the virus-vaccine of this disease is a lifeless substance produced by the bacterium is in conflict with M. Pasteur's facts proving the vaccinating agent in cholera and fowl-cholera to be an organized body. Experiments made by the above-named authors to test M. Toussaint's conclusions show that the bacterium of charbon is not killed by a temperature of 55° C., even after an exposure to it of thirty minutes, but that its vitality is modified; when it really is killed, the solution thus sterilized does not confer immunity from the disease, as M. Toussaint asserts; hence his many failures to confer this immunity. With regard to blood supposed to be sterilized by *filtration*, such blood either gives the disease, or it has no preservative action, and the method of filtration is defective. A difference which appears to exist between the mitigated form of the charbon and that of fowl-cholera is, that it is only the latter which is capable of reproducing itself in a condition in which it maintains its harmless properties; the absence of this property in charbon is a most serious difficulty, and involves great risk in the application of inoculation.

Charbon-vaccin [‡]—Enlarging upon the facts already known of this material, the same three authors state that the bacterium under its most deadly form undergoes sufficient modification by twelve days' exposure to the air in fowls' broth at 42°–43° C. to prevent its being fatal to adult guinea-pigs; in thirty-one days these animals, as well as rabbits and sheep, withstood the effects of a fresh growth prepared at 35° C. from the former one; in forty-three days a fresh growth killed only guinea-pigs a few hours old. The bacterium now never resumes its virulence. It is remarkable that this modified form differs from the deadly agent of charbon only in its shorter and more divided filaments when grown in small quantities: it forms a uniform deposit on the walls of the vessel instead of cottony tufts made up of long threads; but if it forms spores, they give rise to a more deadly form. The bacterium differs from fowl-cholera in this property of producing spores; those formed by its less deadly stages retain the degree of modification possessed by these stages, and do not revert to the original virulence.

M. Bouley,[§] referring to the two preceding papers by M. Pasteur, points out, what M. Pasteur had admitted, that M. Toussaint had already withdrawn his erroneous conclusions referred to.

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[*] Comptes Rendus, xcii. (1881) pp. 662–5.

[†] Cf. this Journal, iii. (1880) pp. 1016–18.

[‡] Comptes Rendus, xcii. (1881) pp. 666–8.

[§] Ibid., p. 668.

Use of small Quantities of Virus in mitigating Effects of Inoculation.*—The honourable rivalry in the extension of knowledge of those diseases which depend on a contagium vivum is sustained by A. Chauveau. He had been led to consider that as comparatively large quantities of the poison of splenic fever succeed in producing an immunity in sheep which are but slightly affected by it, so conversely small quantities ought to do the same for individuals whose receptivity for the disease is great.

His experiments made to test this hypothesis showed that sheep of the native French breeds are invariably killed by the disease when blood containing about 1000 bacilli is introduced into the jugular vein. The method adopted is to dilute infected blood from the guinea-pig until a cubic centimetre of the liquid contains, according to computation, approximately the required amount of the bacterium, and then to inject this quantity, taking care to avoid extravasation. With 600 bacilli to the cubic centimetre, out of two sheep, one died, and the other survived and did not suffer at all in health. Another sheep was infected with 50 bacilli, and at the same time 100 bacilli were introduced into another with the addition to the liquid of 1 per cent. of carbolic acid; in the former case a slight temporary fever ensued, in the latter no inconvenience at all. These two animals, together with the one which survived the dose of 600 bacilli, and two fresh ones, were experimented on together by injection of doses of about 1000 bacilli each. In the case of the survivor of the second experiment, ten days had elapsed since that experiment; in that of the other two survivors, seven days had intervened since their former inoculation. In the present experiment all died of the disease; but one of them, a survivor of the former experiments, lived till the seventh day, and was afflicted with a bacterial meningo-encephalitis, probably indicating that it was already partially protected by the former inoculation. Another five sheep were treated with a preparation of blood taken from the clots in the heart and from the spleen of a rabbit that had been dead nine days but had been kept quite fresh; 250 bacilli in $\frac{1}{2}$ cc. of liquid were injected into each. All withstood the dose, exhibiting only a slight and temporary fever. Of these five, which were re-inoculated six weeks afterwards, four survived the second dose, and the remaining one died. It is possible that the small quantity, and hardly fresh condition, of the liquid used may explain this immunity.

The same investigator deals also with *symptomatic charbon*, or what he calls Chabert's disease, or *bacterian*, as distinguished from *bacteridian* charbon, which is splenic fever. He is able to produce immunity from *its* effects also by carefully graduated injections into the connective tissue. Ten sheep were brought to a state of practical immunity from splenic fever by injections extending over from eight to fifteen months, when a curious but instructive accident took place. A final injection of a very rich infusion was administered to all the animals; but owing to its having been filtered inadvertently through a cloth which had not been cleaned after experiments with the other

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* Comptes Rendus, xcii. (1881) pp. 844–8.

charbon disease, all the animals took this, viz. Chabert's disease, and six of the number died, while the four which were the first to receive the injection survived, owing to the liquid at the top of the vessel used containing fewer bacteria than that at the bottom, which was used for the last six animals; the traces of the inoculation left upon the surviving four similarly depended in their importance on whether the animal was injected first, second, third, or fourth; thus the fourth had an abscess which had not closed at the time of writing. In fine, this and a following experiment show that—1. Chabert's disease is distinct from bacteridian charbon. 2. The virus of the latter does not vaccinate against the former. 3. Algerian sheep are just as subject to Chabert's disease as the French breed. 4. The amount of virus employed has an important bearing on the results. 5. However slight the effects of the first inoculation may be, they confer immunity from the disease.

Manufacture of Vinegar by means of Bacteria.*—According to Pasteur, the formation of vinegar from alcohol is due to the vegetation of *Mycoderma aceti.* Liebig, however, maintained that it is due to chemical and not physiological action, since no *Mycoderma aceti* could be detected by microscopical examination on a shaving from the bottom of a vinegar generator which had been in use for twenty-five years. Mayer and De Knierym, however, distinctly proved that the ferment exists in great quantity on the shavings of the vinegar generator.

E. Wurm has carried out the manufacture according to the directions of Pasteur (sowing the *Mycoderma* by a wooden spatula), and most satisfactory results have been obtained. When the vinegar has reached the required strength, it is drawn off into vats, where it is clarified and freed from *Mycoderma.* The precautions to be observed are—the sowing of pure bacteria, a uniform temperature of 30°, and a well regulated addition of alcohol. The chief advantages of this process are its cheapness and the great economy of space, and a much greater yield.

The generation of "vinegar eels" is of great inconvenience, since by their motion they destroy the pellicle of the *Mycoderma* and prevent its reforming. If they multiply to any great extent, the temperature of the liquid falls, but by preventing the cooling, the parts of the pellicle destroyed may be reproduced, in which case the eels take refuge in the upper parts of the vessel, and form a ring of viscosity above the layer of bacteria. In this process, however, they have not time to multiply so as to become injurious, since the vats are emptied every ten to fourteen days. The *Mycoderma* used for sowing must not come from a liquid infected with eels.

The microscopical examination of the ferment shows that three different forms can be observed. Whether they are from the same organism in different stages of development, or three different organisms capable of producing acetic acid, remains to be proved.

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* Pharm. Journ. (Trans.) xi. (1881) pp. 132–4. See Journ. Chem. Soc. (Abstr.) xl. (1881) pp. 128–9.

Grains of Silica and Micrococci of the Atmosphere.[*]—At the period of the great debate on spontaneous generation between Pasteur and Pouchet, the latter was the first to draw attention to the fact that some of the minute spherical granulations discovered by the Microscope in dust deposited from the air in various regions of the globe were essentially composed of silica. That they had often been mistaken for eggs of Infusoria or for micrococci was very evident, but when the dust was submitted to complete calcination in a platinum crucible the same grains were still visible, with the same forms and dimensions as before.

Dr. T. L. Phipson has more than once repeated this experiment of Pouchet, but has also made the opposite one, and examined the action of heat upon micrococci, diatoms, and Oscillariæ, which are supposed to contain large quantities of silica. There is no doubt but that the dust of the atmosphere reveals to the Microscope, besides the larger mineral fragments, mostly of an angular shape, exceedingly minute circular and spherical bodies, having often not more than 0·001 of a millimetre in diameter, and very similar in size and shape, which resist the action of a white heat in contact with the air and that of strong hydrochloric acid. In some of his observations they were remarkably numerous. Both before and after the action of heat they are more or less transparent. What can be the origin of these singular objects? The same experiments repeated with siliceous Algæ, such as those belonging to the large family of the Diatomaceæ, and with the micrococci of impure waters or vegetable infusions, showed that they do not retain their forms after being subjected to the above treatment, and that in many instances they can be totally destroyed by heat, on the object-glass itself. On the other hand, the fossil diatoms resisted the action of heat and retained their forms. Dr. Phipson can only draw one conclusion from these observations, namely, that the minute siliceous bodies found in the atmosphere are also fossil; "they are micrococci of another age."

Lichenes.

Structure and Development of the Cladonieæ.[†]—E. Wainio investigates this subject from the point of view of the theory of descent.

With regard to the thallus, the author considers the original form to be horizontal, and consequently that the family should be included rather under the crustaceous than the fruticose lichens. In *Cladonia sylvatica* he was able to follow the development of the podetia (the erect stem-like portions of the thallus which bear the apothecia) from a granular crustaceous thallus; and in *C. uncialis* from a scaly layer. The podetium of *Cladonia* he regards as analogous to the stipes of *Bæomyces*. The so-called podetium of *Stereocaulon* has a different origin, and the two genera cannot be regarded as nearly allied. In

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[*] Chem. News, xliii. (1881) p. 28.

[†] Wainio, E., 'Untersuchung über die phylogenetische Entwickelung der Cladonien (in Finnish), Helsingfors, 1880 (1 pl.). See Bot. Centralbl., ii. (1881) p. 164.

respect to the development of the horizontal thallus, the author regards *C. rangiferina* and *papillaria* as the oldest forms.

The mode of development of the cups or scyphi does not afford any reliable generic characters; the same species having sometimes forms in which they occur and others in which they are wanting. Their formation is explained by that of the young podetia. These latter are formed of hyphæ, which curve radially at their apices, the middle hyphæ developing in consequence more strongly than the outer ones. As soon as a fissure is produced between these hyphæ, they separate still more at the apex, and thus the cup-like cavity is eventually formed.

Algæ.

New Maritime Algæ.*—In an enumeration of the maritime algæ of Heligoland (amounting to 534 species), H. Wollny describes four new species.

The first, *Arthrosira reptans*, is a small parasite found on uncorticated Polysiphonieæ (*P. roseola*, *urceolata*, &c.). It consists of filaments of usually elliptical cells 3–5 μ in length, and 2–3 μ in breadth, of an intense carmine-red colour, and covering the filaments of the *Polysiphonia* with various convolutions. Their extreme smallness has prevented their isolation, and no mode of reproduction has been observed. Its affinity is altogether doubtful. The other three new species, belonging to well-known families, are named *Ulva costata*, *Enteromorpha clavata*, and *Lithoderma maculiforme*, the last possibly identical with *L. fluviatile* Aresch., but growing in salt water.

Transformation of a Fertile Branch of Batrachospermum into Prothalliform Branch.†—Under normal conditions, the fertile branch of *Batrachospermum*, the result of impregnation, presents the appearance of a compact glomerulus, of which the larger terminal cells are ovoid or pear-shaped utricles, the envelope of which bursts when ripe, and sets free the condensed contents in the form of a single reproductive body, the oospore (or oosphere). In a singular anomalous condition observed by M. Sirodot, some or all of the last generations of these fertile utricles elongate and abort, while at the same time the basal cells of the utricles develop into articulated filaments composed of very irregular cells and branching irregularly, closely resembling the persistent prothallium of some species of the genus.

M. Sirodot has determined the organism known as *Chantransia* to be the non-sexual form of *Batrachospermum.*

Hauckia, a new Genus of Palmellaceæ.‡—A. Borzi describes a hitherto unknown organism, belonging to the Palmellaceæ, obtained from the island of Favignana, where it occurs on damp calcareous rocks exposed to the sea. It is composed of cells placed in pairs on a long, solid, hyaline, straight or slightly curved stipes. The cells are ovoid or ellipsoid, and multiply by repeated bipartition. The

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[*] 'Hedwigia,' xx. (1881) pp. 30–1.

[†] Comptes Rendus, xci. (1880) pp. 862–4.

[‡] Nuov. Giorn. Bot. Ital., xii. (1880) pp. 290–5 (1 pl.).

contents are green and granular, with a few starch-grains. The increase takes place in two ways: by vegetative division of the cells of which the colony is composed; and by zoospores distinguished into microzoospores and megazoospores. These are formed respectively eight and four in the mother-cell, and escape by a horizontal slit in the cell-wall. No difference in function was detected between the two kinds of zoospore, both germinating after coming to rest. The following is the diagnosis of the species and genus, its nearest allies being *Cosmocladium* and *Mischococcus*:—

Hauckia n. gen. Cellulæ ovales v. ellipticæ, geminæ, stipite longo hyalino recto aut leviter incurvo instructæ, altera apicalis, altera latere interno media parte stipitis inserta; divisio cellularum ad tres directiones alternans; stipitis quasi ramuli repetite bifurcato-articulati, et cellulas in colonias eleganter cespitosas componentes, sed ætate provecta soluti. Propagatio e zoosporis (macro- et micro-zoosporis) usque ad octo in cellulas matricales ortis, et pariete transverse circumscissa, libere erumpentibus; propagatio sexualis adhuc ignota.

H. insularis sp. nov. Diam. cell. 0·004–0·007 mm.; long. stip. 0·15–0·32. Habitat ad rupes calcareas madidas insulæ Aegusæ (Favignana). Leg. Feb. 1879.

Formation of the Sporangia in Halimeda.*—F. Schmitz describes the formation of the sporangia and zoospores in *Halimeda Tuna*, *macroloba*, and *platydisca*. The fructification of the first of these species was described by Bompard as a parasitic organism under the name *Botryophora dichotoma*. According to Schmitz, the branches of the thallus bear on their upper margin dark green tufts of fructification, composed of simple or forked hyphæ on which the sporangia are clustered, their entire space being filled with protoplasm. This protoplasm breaks up into a number of small zoospores, which escape from the sporangium through an irregular slit, and come to rest after a period of active motion. Their further development was not observed.

According to Zanardini, the fructification of *H. macroloba* is quite similar, while that of *H. platydisca* Dcne. presents some differences. This species, although hitherto known only from the Canary Isles, is widely distributed through the Mediterranean, and may be readily confounded with *H. Tuna*, from which it is distinguished by the larger size of the thallus, and chiefly by its fructification. The sporangia are here the swollen apices of short dichotomously branched hyphæ, which spring densely crowded from the entire margin, and also sparsely from the surface of the branches of the thallus. The escape of the zoospores was observed also in this species, but not their further development, nor any conjugation.

Spirogyras of the Environs of Paris.†—P. Petit enumerates and describes thirty-six species of *Spirogyra* from the neighbourhood of

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* SB. niederrhein. Ges. Natur. u. Heilkunde, Bonn, 1880. See Bot. Centralbl., i. (1880) p. 1282.

† Petit, P., 'Spirogyra des environs de Paris' (12 pls.), Paris, 1880. See Bot. Centralbl., i. (1880) p. 1601.

Paris, including one new species, *S. gallica*, allied to *S. sericea*. The following is his classification of the species:—

Section I. Cell-wall recurved in the form of an annular fold at each end of the cell.
  § 1. A single spiral band, rarely two in a few cells.
    A. Middle layer of wall of zygospore smooth (7 sp.).
    B. Middle layer of wall of zygospore dotted (1 sp., (*S. calospora.*).
  § 2. Two or more spiral bands (2 sp.).
Section II. Cell-wall not folded in at the ends of the cells.
  § 1. A single spiral band.
    A. All three layers of wall of zygospore smooth (13 sp.).
    B. Middle layer of wall of zygospore dotted (2 sp.).
  § 2. Two or more spiral bands.
    A. Zygospores ovoid (7 sp.).
    B. Zygospore lenticular or flattened (4 sp.).

Sykidion, a new Genus of Unicellular Algæ.*—On a *Rhizoclonium* gathered at Howth, Dr. E. P. Wright has observed fruit-like structures which he has determined to be an epiphytal unicellular alga allied to *Hydrocytium* and *Characium*, but constituting a new species and genus, to which he gives the name *Sykidion Dyeri*, with the following characters.

The vegetative stage consists of a unicellular organism, with a tough cell-wall, attached by its narrow basal portion to the filaments of *Rhizoclonium Casparyi* (?). It presents somewhat the shape of a little fig. The cell-contents are of a bright grass-green colour. When the cell attains its full dimensions, a second cellulose layer is formed, and shortly afterwards the protoplasmic contents divide into a number of separate masses, which escape by the rupture of the apical portion of the two cell-walls in the form of biciliated green zoospores. On their escape the walls of the mother-plants scarcely, if at all, alter in shape, remaining persistent. These are then of pale straw colour, and might be mistaken for the empty loricæ of an infusorian. The apical slit by which the zoospores escape distinguishes the genus from *Hydrocytium* and *Characium*, in which the slit is always lateral.

Chroolepus aureum.†—This alga, besides growing freely on damp rocks, occurs in conjunction with the lichen *Graphis scripta* on trees, on *Opegrapha saxatilis*, on calcareous rocks, and on other members of the group *Graphideæ*. In a specimen found by Professor T. B. Schnetzler in the free state on a mass of molasse rock at Lausanne, the ramifying filaments bore globular sporanges on their sides. At the sides and base, however, the hyphæ of *fungi* were observed in contact with and penetrating through the walls of the algal cells, and they formed a plexus among the ramifications of the alga.

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* Trans. R. Irish Acad., xxviii. (1881) pp. 27–30 (pl. ii. fig. 5).

† Bull. Soc. Vaud. Sci. Nat., xvii. (1880) pp. 13–14.

Arctic Diatomaceæ.*—Cleve and Grunow describe in detail the diatoms collected by Nordenskiöld, Kjellman, Stuxberg, and Lundström, in the Swedish expedition to the Yenissei in 1875 and 1876, and by Kjellman in Finmark. Those from the Yenissei correspond, for the most part, with the fresh-water algæ of other northern countries; while the diatom vegetation of Finmark is nearly identical with that of Greenland and Spitzbergen. A large number of new species are described, and special attention is paid to the characters of the genera *Achmanthes*, *Pleurosigma*, *Amphiprora*, *Nitzschia*, *Thalassiothrix*, *Podosira*, and *Hyalodiscus*.

Classification of Schizonema.†—A. Grunow discusses the classification of the numerous species of diatoms belonging to the genera of diatoms *Schizonema* and *Berkeleya*, and gives the following general arrangement of the former.

Schizonema C. Ag. (Grun. emend.). Naviculæ contained in simple sheaths, or in those which are again enclosed in common branched sheaths or masses of mucilage. A. RAMOSISSIMA Grun. Loricæ with small central and terminal knots, lying close to the end, transverse striæ nearly parallel or somewhat radial, finely punctated; the dots so placed that they form fine but sharp longitudinal lines. *a. Monema.* One-rowed, or crowded in simple sheaths. *b. Micromega.* Sheaths in large numbers in thick branched mucilaginous common sheaths; not sharply separated from the previous section. B. RADIOSA. The loricæ have delicately punctated transverse striæ which stand radially in the middle, and towards the ends turn in an opposite direction; the punctation of the striæ does not form clear longitudinal lines; a small smooth round space round the central knot; end-knots near the end of the lorica. *a. Colletonema.* Fresh-water forms with delicate simple sheaths; frustules in one or a small number of irregularly grouped rows. *b. Schizonema.* Marine forms with simple or compound sheaths. C. PSEUDO-ENCYONEMA. Loricæ similar to those of the last group, but more strongly striated, and somewhat unsymmetrical; end-knots, especially in the longer frustules, at some distance from the apex. D. PSEUDO-VAN-HEURCKIA. Loricæ similar to those of *Navicula* (*Van Heurckia*) *rhomboides.* E. COMOIDIA. Loricæ with radial, strongly punctated striation; end-knots at some distance from the apex; a larger or smaller round smooth space round the central knot; striation much more delicate than in group C; loricæ perfectly symmetrical. F. Loricæ resembling *Stauroneis*, a thickening reaching from the central knot on both sides to the margin of the lorica; it is not, however, smooth, but covered with transverse striæ; when dry the thickening is more evident; when laid in canada balsam, only the two central transverse striæ are strongly marked; the punctation of the parallel transverse striæ forms delicate longitudinal lines.

Under these groups are arranged and described forty-nine species, with a great number of varieties.

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* Cleve, P. T., and Grunow, A., 'Beiträge zur Kenntniss d. arktischen Diatomeen' (7 pls.). (4to, Stockholm, 1880.)

† Bot. Centralbl., i. (1880) pp. 1506–20.

Diatoms in thin Rock Sections.*—W. Prinz, in the first place, refers to the contrary opinions that have been held as to the sculpturings of diatom valves, some considering them elevations, others depressions, and others perforations, the phenomena of interference and diffraction serving to conceal the true structure. Photomicrography was not found a certain guide, as Dr. Woodward's photographs showed elevations, and those of C. Günther † openings in *P. angulatum.*

The author recently received some pieces of a diatomiferous rock from Nykjobing, Jutland, the examination of which has enabled him, he considers, to establish the true character of the "markings." The rock is almost as hard as limestone, and exhibits bedding due to the superposition of very thin laminæ. Slices at right angles to the bedding planes gave sections of the diatoms exhibiting the form of the sculpturing on the surface of the valves. In order to render the structure of the sections more clear, and to remove any impurities, it was found advisable to treat the prepared films of rock with hydrochloric acid before mounting them in balsam. In thin sections, properly prepared, the diatoms will be found cut in every plane.

The three species described by M. Prinz are *Coscinodiscus oculus Iridis*, *Trinacria Regia* Heib., and *Coscinodiscus excentricus.* These he examined, in the first instance, in a free condition and with the frustules entire; but it is unnecessary to reproduce the descriptions of that part of the examination.

Coscinodiscus oculus Iridis is covered with a reticulated design, the result of the superposition of two layers; the upper formed of hexagonal cavities resembling the alveoli in a honeycomb, and the lower composed of small areolæ, convex according to some, concave according to others, placed each in the centre of one of the hexagonal depressions.

FIG. 114.

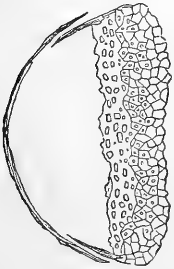
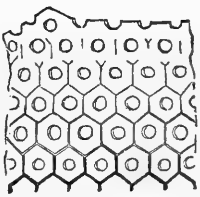


FIG. 115.



A very oblique section, cutting successively the two layers composing the valve, exhibits their structure separately. Fig. 114 shows one of these sections, and Fig. 115 the details much enlarged. In the latter figure the hexagonal alveoli (more and more cut away) are seen to disappear completely, and leave the lower layer with its areolæ bare. The margin of the section clearly shows that these areolæ are

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* Ann. Soc. Belg. Micr.—Mém., vii. (1880) 12 pp. (1 pl.).

† See this Journal, iii. (1880) p. 891.

perforations, as originally suggested by Mr. Stephenson. Were they small elevations, they could not escape observation in exactly normal sections, where, however, they were not seen.

The true character of the markings may also be determined without the sections. In preparations containing diatoms collected by dissolving the rock, valves are found which are partly cleft, and the upper layer of which is partly separated from the lower. The former examined by itself shows only a network of hexagonal meshes. The lower layer has a plane surface traversed by circular openings, as is established by oblique light. If the preparation is not dry, it is sufficient to press the cover-glass on the place where the valve is in order to break it. The margins of the fractures present the appearance shown in Fig. 115.

As to the small points or circles figured on the surface of the pretended elevations by certain authors, they are due to the effects of diffraction, and disappear when an open areola is examined. The same phenomena are observable in *Trinacria Regina*, although less distinctly, the openings of the latter being larger.

Trinacria Regina Heib. was in the same way found to be crowded with small circular apertures, as was evident in the fractures, which had the same aspect as those of *Coscinodiscus*, and also from longitudinal sections of canaliculi corresponding to the apertures.

The nature of the sculpturing on the surface of the small diatom *Coscinodiscus excentricus* was excessively difficult to determine clearly, the examination of the fractures scarcely sufficing owing to the smallness of the areolæ.

The author points out that this method of examining diatoms is also applicable to recent forms. By imbedding them in cement, sections may be obtained by means of which many of the existing difficulties will be solved, and the structure of these organisms better understood. He has tried for *P. angulatum* a mixture of oxide of zinc and silicate of potash, but although it polishes well it cannot be cut sufficiently thin.

Mr. J. Deby, on the other hand,* altogether contests the idea of the perforation of the valves, and is convinced that the so-called openings are an optical illusion. He bases this view mainly upon observations of diatoms by reflected light, that is, as opaque objects.† An examination of such objects as *Eupodiscus argus* or *Pleurosigma formosum*, mounted dry without cover-glass, using a power of 1000 or 1500 diameters, and either the vertical illuminator or the Woodward prism, would, he thinks, for ever convince M. Prinz of the non-existence of external orifices. In addition to his own observations, M. Deby refers to the experiments first made in 1851 by Bailey, who dissolved diatoms under the Microscope in fluoric acid, and also to the collodion impressions of Mr. Wenham.

Another mode of showing that the openings are illusions is to allow a highly coloured fluid to run in amongst some diatoms lying dry on a slide. The fluid will be seen to be rapidly diffused (by

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* Bull. Soc. Belg. Micr., vii. (1881) pp. lxxix.-lxxxii.

† *Sed qu.* as to opaque illumination. See this Journal, *ante*, p. 364.

capillarity) *between* all the siliceous globules, but never penetrating them, as it must if there were perforations.

In a number of genera the valves are formed of two superposed layers, and in this case it often happens that the internal layer is perforated by numerous orifices more or less circular, but these, Mr. Deby is certain, do not perforate the external valve.

Dr. L. Flögel intends to make a further series of sections of diatoms by the microtome of his invention, by which he has been able to make 150 consecutive sections of the brain of the cockroach. These sections will probably decide the question of orifices.

Count Castracane also discusses * the question, and reiterates his opinion that the supposed orifices in *P. angulatum* are raised granules. This is in accordance with the view of Dr. Wallich, and his observations on the action of moisture introduced among diatoms mounted dry. He considers, therefore, that the microphotographs of C. Günther are not correct, in so far as they show openings, and he is confirmed in this view by his own experience with microphotography. In order to eliminate a source of error in the Microscope, by which concavities are shown where convexities really exist, and *vice versâ*, the Count has recourse to binocular stereoscopic vision, examining a diatom under two different aspects. Thus *Craspedodiscus microdiscus* magnified 535 times invariably appears with the markings in distinct relief.

Moreover, the sections of *P. angulatum* and *P. balticum*, which M. Flögel succeeded in making some years ago,† showed clearly that small interstitial cells existed in the thickness of the valve corresponding to the elevated granules, so that orifices cannot, he considers, exist.

Movements and Vegetative Reproduction of Diatoms.‡—Recent investigations of E. Hallier on the Diatomaceæ have been directed chiefly to the phenomena of cell-division and to the nature and cause of their peculiar movements.

He asserts that the processes of cell-division take place in exactly the same way as in many other algæ. That, for example, in *Melosira* closely resembles those which Pringsheim describes in *Œdogonium*, while the course is still simpler in *Navicula*, *Frustulia*, *Surirella*, and other boat-like forms. This, he considers, disposes of the "box-hypothesis," which always presented much that was improbable. No indication of the formation of boxes is presented with a magnifying power of nearly 2000; while the process of division can be seen completed in a very simple fashion.

The more ordinary theory of the cause of the movements of diatoms is that they are due to the rotation of the protoplasm, which projects slightly through a crevice in the front. No trace, however, of such a crevice can be detected by the objective mentioned; while it is easily seen that the movement is far too complicated for so simple a con-

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* Bull. Soc. Belg. Micr., vii. (1881) pp. lxxxvi.–ix.

† See Arch. f. Mikr. Anat., vi. (1870) p. 472.

‡ Hallier, E., 'Unters. üb. Diatomeen; insbesondere üb. ihre Bewegungen u. ihre vegetative Fortpflanzung.' 32 pp., 2 pls. (8vo, Gera-Untermhaus, 1880.)

trivance, which scarcely finds a parallel in the entire vegetable kingdom. The causes of the movement are seen to reside in the contractility of the entire young diatom-cell, closely resembling, therefore, that of the Flagellate Infusoria. This result is of some importance in relation to the theory of descent, indicating that diatoms are in fact neither animals nor plants, or both at once, their mode of nourishment, formation of auxospores, and mode of cell-division associating them with the Conjugatæ, while their movements are those of the lower animals. With the exception of the Oscillatorieæ, where the motion appears to be due to the same cause, a movement of this peculiar kind of the entire vegetative cell-wall scarcely recurs in the whole vegetable kingdom.

The "box-hypothesis," and the ordinary theory of the movement of diatoms, have been founded on the false premise of the absolute rigidity of the "lorica" of the young diatom-cell. The complete inaccuracy of this idea can, the author thinks, be easily proved.

The instruments used by the author in his investigations are the dry and the water-immersion systems L. and M. of Zeiss up to 2500 linear magnifying-power, as well as the $\frac{1}{18}$ oil-immersion. As long as it was possible, only low-power eye-pieces were used, although one of the principal advantages of the oil-immersion system is that high-power eye-pieces can be employed without injury to the clearness and definition of the images.

As a favourable instance of the formation of "boxes," should this be a correct interpretation of the phenomena, the author took the common *Melosira varians*, in which the secondary side is as long as possible;—understanding by "primary side" (*Hauptseite* of Rabenhorst) the side parallel to the plane of division; by "secondary side" (*Nebenseite* of Rabenhorst) the side at right angles to the plane of division. Careful observations, however, did not give the least support to the correctness of this hypothesis, the difference in the size of the two daughter-cells which result from the cell-division being due to differences in nutrition or in the other vital conditions. A new formation of cell-wall (*Häutungsprozess*) takes place before the division, and this is especially well seen in the formation of auxospores. In this process, by the formation of a circular division in the centre of the cell, the cell-wall is split into two cylinders, open within and closed without, which then separate from one another by the gradual expansion of the protoplasm. The further development of the auxospore is then described in detail. Between the formation of auxospores and the ordinary cell-division there is this difference, that in the latter, before division, the cell which is thus split increases to double its original length, so that each of the two newly formed daughter-cells about equals the original mother-cell in length; while the auxospore considerably exceeds double the length of the mother-cell. The author regards the formation of auxospores as an arrested process of cell-division, or as a process of rejuvenescence. When the auxospores are disposed in an isolated manner in an elongated vegetative chain, their position is undetermined; but when they lie one immediately behind another in the chain, the anterior and posterior ends of the auxospores are always in contact with one another in pairs. With the "box-hypothesis," the theory that the individual is continually decreasing in size must also be abandoned. The young cell-wall of the newly formed cell is very soft and extensible, and readily attains the size of that of the mother-cell.

The auxospore germinates by a simple process of cell-division, commencing with a division wall at right angles to the axis of growth.

Frustulia saxonica presents another favourable example; but in it also Hallier determined the incorrectness of the "box-hypothesis." The process of cell-division differs, however, in some important points from that in *Melosira.* There is no splitting of the cell-wall of the mother-cell; the division is, on the contrary, preceded by an extension of the cell-wall in the direction of the transverse diameter of the secondary side, and a cell-wall is then gradually formed dividing the individual into two halves along its longest diameter.

With respect to the *movements* of *Frustulia*, *Navicula*, and other similar forms, the author makes the following observations. The movement usually takes place on the primary side, one end being somewhat depressed, the other end being somewhat elevated and moving backwards and forwards, the individual gradually advancing. Two incorrect assumptions have, however, been made in order to explain this movement; viz. that the motion is always a gliding one, and that it is caused by a crevice on the primary side (which was even alleged to have been seen in *Navicula* and *Frustulia*), through which the protoplasm rotating in the interior of the cell is in communication with the outer air.

Neither *Navicula* nor *Frustulia* shows, with the highest magnifying, the least indication of a crevice; nor is the rotation of the protoplasm of such a nature as in the least to account for a movement backwards and forwards of the frustule, being quite of the same nature as that which so commonly occurs in living vegetable cells, and affording no explanation of the power of movement of the cell. The following explanation of these movements is offered by the author.

When the movement is carefully watched for a considerable period and in a number of specimens, it is seen to be subject to a great variety of modifications. If the movement were of a gliding nature, and due to protoplasm exuded through a crevice, the primary side must always face the observer, because in this position only could the rotating protoplasm be in contact with the glass plate. So far, however, is this from being the case, that the diatom is frequently seen to be progressing as quickly on its secondary side, and very often the position is constantly shifting. It is sometimes fixed to the glass plate by one of its viscid ends, swaying backwards and forwards, a phenomenon quite inexplicable on the old hypothesis. In some species, and especially in *Cymbella*, violent convulsive movements are frequently seen, and even the swaying motion is by no means always very regular. All attempts hitherto to explain the phenomenon have proceeded on the supposition that the "lorica" or cell-wall of the diatom is very rigid. In the young individual, while in a motile condition, this is by no means the case, the cell-wall being extremely flexible and elastic. The siliceous particles, which increase in number with the age of the cell, are at first by no means fixed, and the entire membrane is very flexible. This is readily seen when one individual comes into contact with another. If a young motile cell is treated with chlor-iodide of zinc, the entire cell, including the so-called "lorica," takes a yellowish-brown tint. There is, in fact, no true cell-wall; the outermost siliceous layer is rich also in nitrogen, and must be regarded simply as a denser layer of protoplasm. The condition of the older cell is very different, being then enveloped in a brittle true cell-wall, destitute of nitrogen; but in that condition it is no longer motile. Very careful observation with a powerful oil-immersion system, shows that the whole outer layer of the cell is motile, the apices swaying backwards and forwards, and the layer displaying constant irregular contractions, altogether resembling those of the Flagellata. The statement is therefore correct, that movements in the protoplasm are the cause of the motility; not, however, in consequence of rotation, but rather of contractions of the entire organism.

The general conclusions may be summed up as follows:—

1. *Frustulia*, *Navicula*, *Cymbella*, and probably all motile diatoms, have in the young condition no true cell-wall, but are, like the flagellate infusoria, naked protoplasmic cells, clothed by a delicate, contractile, siliceous, extremely flexible layer, which only subsequently becomes a true non-nitrogenous cell-wall.
2. The motility is due to the contractile layer of protoplasm, and is an extremely complicated phenomenon.
3. There is no crevice in the mid-rib of the primary side.
4. There is no regular rotation of the protoplasm which can serve as a cause of the motility of the cell.
5. The so-called "box-hypothesis" is not confirmed (in *Navicula* and *Frustulia saxonica*).
6. Cell-division is preceded by an increase of the transverse diameter of the secondary side of the cell in *Frustulia* and *Navicula*, but there is no bursting of the outer cell-wall as in *Melosira*. This is accompanied by a division of the nucleus, and a movement of the two daughter-nuclei to the primary side.
7. The cell divides by a longitudinal division-wall, which is at first simple, but afterwards becomes double.
8. After the separation of the sister-cells they increase at the ends in a transverse direction, and thus form the gelatinous but siliceous non-nitrogenous apices, united to one another by the longitudinal ribs.

Uses of the Study of Diatoms.*—Dr. M. Lanzi points out how the study of diatoms is connected with medicine, geology, and agriculture.

As regards *medicine*, the well-known "edible earth" consists of

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* Lanzi, M., "Utilità dello Studio delle Diatomee," R. Medic. Accad. Roma, Atti 1880, Seduta 28 Dec. 1879, pp. 1–13.

diatoms containing a small amount of organic matter; such are the earths of Java (consisting mainly of *Melosira orichalcea*), Lapland, the mountain-meal of Switzerland and Finland, and the fossil-meal of Mount Amiata, in Italy, which contains about 80 species. A mixture of marine algæ (*Fucus*, various species, *Rhytiphlœa*, *Cladophora*, *Ceramium*), of Corallines and Sertularians, is known to druggists under the name of Corsican moss, in which as many as 120 species of diatoms have been found. They also occur as the Carrigeen moss (*Chondrus crispus*) used in pharmacy, and on other marine plants, whose ashes have been from time to time used as medicine (e. g. *Ulva lactuca*, *Fucus vesiculosus*). In this connection, however, they must be regarded as indifferent substances, producing no appreciable effect when thus taken, as 84 per cent. of them is composed of silica, and only 12 per cent. of water and organic matters; the latter constituents being the protoplasm and the accompanying sap and the endochrome, which are all, with the exception of the phycoxanthin of the latter body, already found in the accompanying Algæ. They have a further interest, in the part which they play when living in fresh waters, in purifying them from the excess of carbonic acid and waste azotized matters, and in giving out at the same time more oxygen than any other aquatic plants.

In their relation to *geology*, diatoms furnish proofs of the aquatic origin of the strata in which they occur, of their age, and of the saltness or freshness of the water in which they were deposited, and of whether near the coast or in deep water, by the difference between the species which are associated with each of these conditions.

Diatoms are connected with the useful arts through *agriculture*, to which they are of assistance under the form of guano. Water rich in diatoms is more fertilizing than that which is not so, as the latter generally contains an undue amount of mineral salts.

Diatoms are used—as tripoli—to polish metals, stones, and jewels, and form a constituent of dynamite. Their most important application to the arts here mentioned, is that of serving as tests for the Microscope.

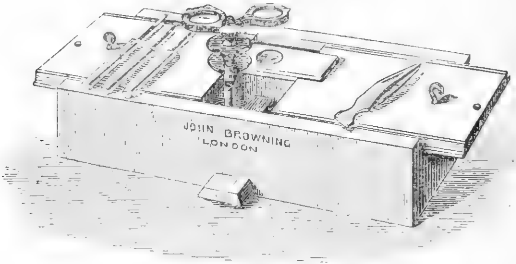
MICROSCOPY.

a. Instruments, Accessories, &c.

Houston's Botanical Dissecting Microscope.—This instrument (Fig. 116), designed by Mr. D. Houston, author of 'Practical Botany,' is intended to provide working botanical students with a dissecting Microscope at a very low cost.

The box measures, when closed, 9 inches long, 4 inches wide, and 2 inches deep, and is so constructed that, by using a divided sliding lid (which acts as a support for the dissecting stage), a rest for the wrists is secured while the hands are employed in dissecting. The duplex lens, which gives three powers, magnifying 4, 6, and 10 diameters, is screwed to the end of a brass focussing tube, which moves upon a brass pillar attached to a sliding bar at the bottom of the box. The lens may at any time be unscrewed and carried in the pocket. The dissecting stage is a cork slide, plain on one side for general work, but provided with a shallow cell on the other, for the dissection of such objects as small glossy seeds which "fly" under the needles. A pitted glass slide, to be used when the object is best dissected under water, is also provided.

Fig. 116.



Jaubert's Microscope.—Fig. 117 shows a Microscope of somewhat unusual form, made by M. Jaubert of Paris as long ago as 1866.

Besides the ordinary movement of inclination from the vertical to the horizontal position, the stand is provided with a *lateral inclining movement* at right angles to the former, by which the optical body and stage can be completely inverted on an axis running through the trunnion bar. M. Jaubert claims that this facility for inverting the Microscope may be of use in chemical experiments.

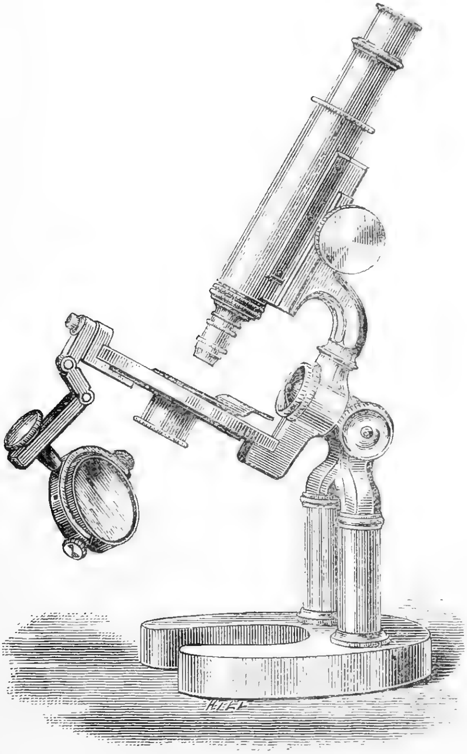
The attachment of the *mirror* can also be slid round the edge of the stage from side to side, and sundry articulations give a great range of motion to the mirror either above or below the stage.

The *fine adjustment* is by means of a differential screw attached to the nose-piece of the optical body. This system appears to have been experimented with at various intervals since the days of Pritchard, but has not met with permanent favour. In the 'Quarterly Journal of Microscopical Science,' iv. (1856) p. 92, is a paper "On a New Form of Microscope," by Mr. R. Warington, with a figure of the fine adjustment, which was stated to be "constructed on the principle of a common union-joint, the outer half of which works in a male screw at the extremity of the body-tube, and acts against a spring in order to maintain a constant bearing. . . . ." Mr. James Swift also some years ago devoted attention to working out a somewhat similar plan, and in fact exhibited a Microscope embodying the fine adjustment at the International Exhibition of 1862. It may also be noted that a Microscope of amateur construction (by Mr. W. A. Bevington) having a fine adjustment of this kind at the nose-piece of the body-tube, has been exhibited several times at the Society since 1875 when it was made.

The fine focussing by means of a differential screw, together with an analogous system for the coarse adjustment, and several other curious mechanical movements as applied to Microscopes, &c., formed the subject of an elaborate series of patents registered in England by M. Jaubert in 1866, to which we propose to refer hereafter.

Mr. J. Mackenzie also describes and figures * a swinging sub-stage made upon the same principle as the preceding. To the under part of the fixed stage-plate an angular plate is attached, having a swivel joint on which a stem with rack swings. A pinion works on the rack and carries an arm with either a single or compound lens which should be so adjusted as to be central with the optical axis of the Microscope. At the end of the stem is a small concave mirror. The lens can be raised or lowered by the pinion or swung to any angle below or above the stage. The angle-plate should be made and fixed so that the centre of the movable joint or swivel coincides with the top of an ordinary object-slide when it lies on the stage.

FIG. 117.



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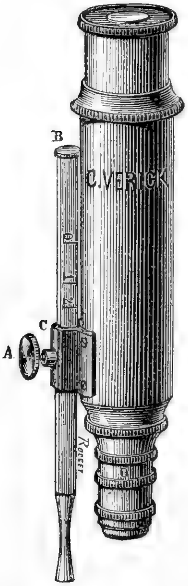
* Journ. Quek. Micr. Club, vi. (1880) p. 170, pl. xii.

Vérick's Skin Microscope.—This (Fig. 118) is intended for the examination of the skin. The tube, with eye-piece and objective, is of the usual form, but is attached to a lateral bar B, which is of brass, with a piece of ivory at the lower end. This bar serves for the adjustment of the Microscope to the proper focus. It is graduated in accordance with the objectives used, and when the number corresponding to the particular objective is brought to the point C, and the end of the bar rested upon the object under observation, the surface can be examined with facility. The screw A serves to clamp the bar and tube together.

Fig. 118.



Watson's Microscope-Stand. — This new stand (Fig. 119) presents several points of novelty, the most notable of which is the inclining motion of the limb carrying the optical body and stage on an axis in a line with the object on the stage. By the simple inclination of the limb, varying effects of oblique illumination can be obtained direct from the mirror, which can be attached for this purpose to the centre of the base, and is then independent of the inclination of the limb.

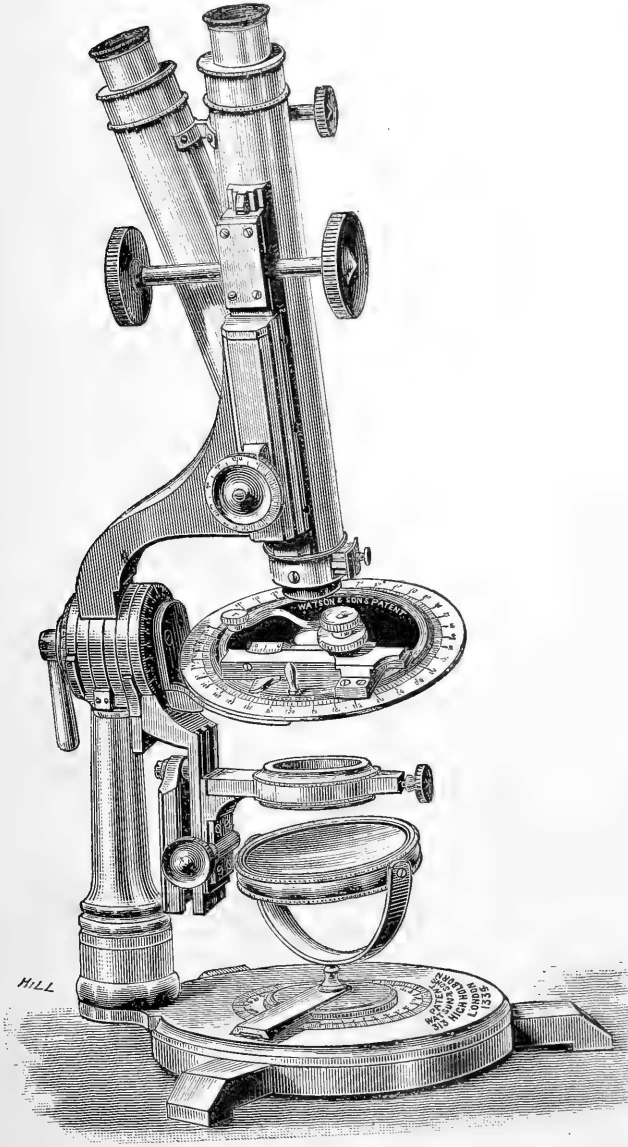
The base of the stand is circular, with three projecting claws; on this base a disk of metal carrying the pillar-support (of the limb, stage, &c.), is made to rotate on the perpendicular optic axis (as in Nachet's Microscope, described in vol. iii. p. 873), and a graduated zone shows the angle of rotation. In the centre of the base a smaller disk (projecting slightly above the general plane) is made to rotate; this disk has a groove into which the mirror-fitting slides, and a spring-notch shows the axial position. The sliding fitting allows the mirror to be placed considerably out of the axis radially, and then the rotation of the circular moving baseplate gives a considerable range of obliquity of light in azimuth—the light from the mirror remaining constantly directed upon the object; this facility obtains with all inclinations of the limb and stage because the object itself forms the centre both of the azimuthal rotation and of the inclination in altitude.

The limb is mounted in a "cradle" joint, at the top of the pillar, permitting inclination from the perpendicular. The angle of inclination is registered upon a graduated ring against the clamping screw.

The optical body is mounted not as usual on the front of the "Jackson" limb, but on the side of it (the *side* of the limb is thus converted into the front).

The coarse adjustment is by the ordinary rack and pinion; the fine adjustment lifts the optical body in a separate slide-fitting by means of a wedge-shaped block acted upon by the conical end of a

FIG. 119.



fine micrometer-screw. The focal distance can be measured by a scale engraved on the slide-fitting.

We figured and described the mechanical stage on pp. 300–1.

The substage-bar carries the usual centering fitting for condenser, &c., and swings forwards or backwards concentric with the object on the main stage, and the obliquity of the swing can be registered on a graduated ring immediately behind the stage. The construction is similar to that known as the Ross-Zentmayer. An extra swinging bar is attached behind, into which the mirror can be slid for use in combination with the condenser, &c.

We understand the swinging substage will be somewhat modified by Messrs. Watson in future constructions.

Eye Shade for Monoculars.—Mr. E. Pennock, of Philadelphia, has devised for use with monocular Microscopes the eye shade shown in Fig. 120. The microscopist is always supposed to keep the eye not in use open, but it is well known that there are many who are unable to do so except at the sacrifice of the visibility of the details of the object, especially when, as at soirées and public exhibitions, there is a considerable glare of light upon the table on which the Microscope stands. Some of the devices hitherto in use have been more elaborate than that now proposed, which has the merit of the utmost simplicity and prevents the possibility of other objects being confused with the microscopical image. It slips over the cap of the eye-piece.

Fig. 120.

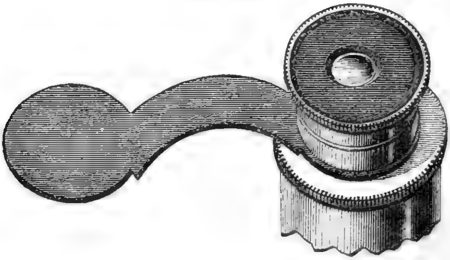
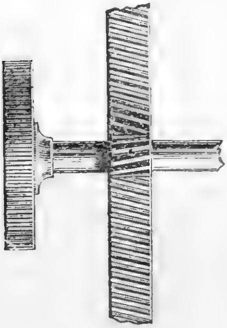


Fig. 121.



Diagonal Rack-work and Spiral Pinion.—The occasional application of diagonal rack-work and spiral pinion to the mechanism of the Microscope, dates back from at least the days of Andrew Pritchard. In recent years it has also been adopted, particularly by Ross and by Swift, the latter using it throughout his construction of instruments. From the experience that we have had of this arrangement, we find that it produces a smoother motion than the usual straight rack and pinion; the spiral pinion gripping the rack over a broader surface and holding it for a longer space during the motion.

Fig. 121 (from a drawing communicated by Mr. Swift) shows the construction of average size.

New Fine Adjustment.*—Mr. E. Gundlach, of Rochester, U.S.A., has introduced a device by means of which an extremely slow, fine adjustment can be obtained in addition to the ordinary coarse screw movement. It is described as follows:—

"In working high powers, microscopists have felt the need of a finer adjustment than the ordinary micrometer-screw, which cannot be made much finer and still be durable enough. This need is now supplied by the combination of two screws which give a resultant motion equal to the difference in the threads employed. One of these screws is a little coarser than the ordinary micrometer-screw, and may be used alone as a fine adjustment, and a change can be made instantly from this to the finer motion. Either is given by one milled head located in the usual position of the fine adjustment screw-head on Gundlach's Microscopes, and the change is made by turning a smaller clamping screw having its head over the former. By tightening the clamping screw, the adjustment is in order for the work of the combination; by loosening, for that of the coarser screw only. As the thread of this is a little coarser than the ordinary micrometer-screw, it alone gives a better motion for medium powers than the fine adjustment in common use, a second advantage of the invention."

Oil-immersion Objectives with Correction Adjustment.—With regard to the advantage or otherwise of adopting the correction-adjustment to oil-immersion objectives, Professor Abbe appears to have thought † the errors of centering, likely to be introduced by the movable mounting required for the adjustment, would be so sensibly felt with the high apertures for which the formula was designed, that it would probably be advantageous not to provide the adjustment, but to mount the lenses in fixed settings. Dr. Woodward, of Washington, has also expressed his approval of the fixed settings on the ground that the formula does not practically need a correction-adjustment. The photographs of difficult test-objects produced by him with the Abbe-Zeiss oil-immersions prove, at any rate, that the particular objectives referred to certainly yielded excellent definition with fixed settings.

The objectives recently made on this formula by Seibert and Krafft, of Wetzlar, are also similarly mounted, as are the most recent ones of Gundlach, of Rochester, N.Y.

In England Mr. Stephenson ‡ has acquiesced in the *non-adoption* of the correction-adjustment for these lenses.

On the other hand, Mr. Tolles, of Boston, Mass., and Mr. Spencer, of Geneva, N.Y., have mounted their best objectives on this formula with adjustment. It is also known that Messrs. Powell and Lealand prefer the mounting with correction-adjustment,§ which they have

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* Amer. Natural., xiv. (181) p. 346.

† See this Journal, ii. (1879) p. 261 *note.* ‡ Ibid., i. (1878) p. 51.

§ Ibid., iii. (1880) p. 1084.

applied to their most recent $\frac{1}{12}$ (exhibited at the Society on November 10th last).

The convenience of the adjustment has been lately brought out remarkably in testing with the $\frac{1}{12}$ various media for immersion. For instance, with the solution of sulpho-carbolate of zinc in glycerine, having refractive index 1·525 (nearly), the adjustment permitted the lenses to be slightly approximated, and the result was a more perfect correction than by using oil of cedar-wood. The correction-collar was also employed advantageously (with the same lens) on various specimens of *Podura*, some of which, not being in close proximity to the cover-glass, could not have been viewed so well had the lenses been mounted in a fixed setting. These facts were plainly developed by immediate comparisons with several oil-immersions in fixed mounts—by Zeiss, Seibert and Krafft, Gundlach, and Powell and Lealand, which failed to give correct images on all the scales that were not in very close adherence to the cover-glass.

Mr. A. H. Bragdon, of Bangor, Maine, U.S.A., also writes to us on this subject, recommending Mr. Tolles's application of the correction-adjustment on the ground that the *same* objective that is corrected at "closed" point for homogeneous immersion may be used for preliminary observations with water-immersion, the screw-collar enabling the observer to adjust the lens for that medium. He states that, "to the worker this is a great desideratum, and saves a multiplicity of objectives. No one can appreciate this more than a physician who constantly desires to examine with a high power many temporarily mounted objects."

Mr. Bragdon also mentions that he has received from Mr. Tolles a solution of chloride of cadmium in glycerine of exactly 1·525 index. Since the receipt of his letter we have examined a specimen of the fluid (sent by Mr. Tolles), and have found it work well with homogeneous-immersions provided with correction-adjustment, notably a $\frac{1}{10}$ made by him, and Powell and Lealand's $\frac{1}{12}$ above mentioned.

Seiler's Large Stage.—Dr. Seiler, of Philadelphia, has devised a large stage, arranged with mechanical movements, so that it can be made to traverse a distance of about four inches each way. It is claimed to be particularly valuable for examining large specimens, such as sections of tumours, the vocal organs, or anything requiring a large stage movement to bring the whole of the structure successively into view.

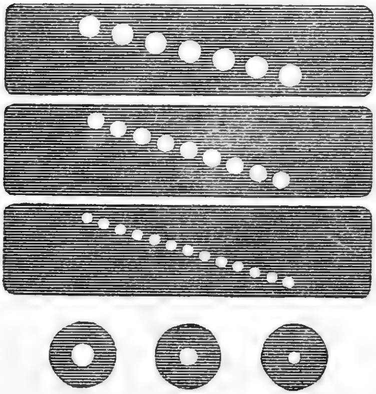
Sliding Stage Diaphragms.—Dr. J. Anthony writes as follows:—

"In going through a series of experiments during the last few months, on the comparative advantages of diaphragms above and below the condenser of the Microscope, I arrived at such satisfactory results that it may be worth while to place them on record; not as a finality, for nothing is likely to be final with the Microscope for many a long day, but that others may take up the matter where I leave it, and that I may have the satisfaction of feeling that I have thought out a most efficient and economic appliance so far as it goes.

Careful manipulators of the Microscope have long felt the damage to the sight which was involved in the attempt to gaze at objects in a full glare of light, and so it came to pass that 'Iris' and other diaphragms were introduced below the condenser to allow only a very small pencil of light to be transmitted; but there was a consciousness that the device was, in degree, tantamount to weakening the light, and it has always been an axiom in microscopy that 'a weak light will never give a brilliant image'; and then came an attempt at additional intensity through a lamp with a flat flame. For resolution this answered admirably, and necessary obliquity obviated glare, but with axial illumination this intensity was not easy to deal with. If the 'Iris' was used to moderate light to a small aperture, lines were thickened, and images of objects looked coarse; if the diaphragm was not freely used the image was poor, flat, and milky, and drowned in a flood of radiance. So diaphragms were constructed, as 'Calotte,' &c., which would act above the condenser, and so, when the full body of light was focussed on the object, the aperture in the condenser would suppress such a number of rays as went rather to injure the image.

There is a positive value in such appliances, and provided they are made sufficiently thin, so as to be easily revolved and easily got at for manipulation, they will do all, or very nearly all, I claim to get from the small and simple contrivance I am about to describe. But it is not to be lost sight of, that these special forms of revolving diaphragms applied above the condenser must of necessity be costly, and confined almost exclusively to what are classed as 'expensive Microscopes,' and it is no small satisfaction to be able to say that experiments have shown me that equal or even superior effects can be got with appliances costing but a few pence, and requiring little more skill in manipulation than a fair amount of delicacy of touch. We recognize that the conditions to be fulfilled are to interpose some screen between condenser and glass slip carrying the object, which shall work easily in the very small space between the usual so-called $\frac{4}{10}$ condenser and the said slip, and which can be made to cut off gradually from the blaze of light all the rays not actually wanted for the perfect illumination of the object under inspection, and at the same time, that such a screen shall be as simple and as little costly as may be compatible with thorough efficiency. It will be seen how far these conditions are met. It would be useless to detail the hundreds of forms of screens or diaphragms experimented on, —all imaginable shapes of aperture and of all sizes, squares, triangles, slits, slots, 'cat's-eyes,' bars, and central stops to apertures, and all more or less unsatisfactory in some way; better to narrate the settling down into the conviction that there really was great advantage in the employment of the simple means shown in the accompanying diagram, where all is given in actual sizes used. It will be seen that there are three slips, of either thin smooth card or vellum, each 4 inches by a full $\frac{7}{8}$ inch, and in each card are punched a row of apertures *oblique to the long axis of the card*, and consequently to the slip of glass when the card as intended is placed beneath the slip upon the stage of the Microscope. It will be seen from construction that on any stage, and with the object to be looked at mounted even excentrically, there would be no sort of difficulty, when the slip is duly clamped and the object brought to centre with a low-power objective, in moving the perforated 'stage diaphragm' right or left so as to let the object be *in the centre of a circle of light.* With any power used, it is easy to understand that a slight push or pull at one of the free ends of the card will, without disturbing the object in the slightest degree, cut off more and more of the unnecessary rays, and as these are gradually eliminated, it will be found that the image changes from a poor, flat, drowned effect to one of great boldness and brilliancy. It is here that the delicacy of touch comes in, for the finest effects of detail are often got with an all but imperceptible movement of the card. One may say that the card material lends itself better to this delicacy than perhaps metal would do, inasmuch as the small amount of friction between slip and card and card and stage respectively, keeps this simple and efficient diaphragm in its place, and it is evident that if card or vellum be the material employed it will have the additional advantage of not scratching the condensing lens. Three apertures of diaphragm were found available, $\frac{1}{4}$, $\frac{3}{16}$, and $\frac{1}{8}$, all with certain advantages with different powers and different classes of objects.

Fig. 122.



It was both interesting and useful to try against this stage diaphragm the effect of corresponding apertures in so many "caps" to the condenser. The circumstances would of course be a little different, inasmuch as with cap to condenser in order to modify the light the said condenser would have to be moved bodily, and the effects would be got by a quasi marginal instead of a central pencil, and so be analogous to some of the effects of oblique light—a condition not at all desirable except for 'resolution' of very diaphanous objects. Anyhow, aperture for aperture, experiment demonstrated that with delicate touches far finer effects could be got from the stage diaphragm than from any sized cap on the condenser, perchance from the light being absolutely central to begin with. One can understand that many conditions would have to be considered in order to determine the point, but I have thought it best to confine myself to practical points. One practical point soon made itself evident, and that was, that the aperture either in card or cap could not be reduced beyond a certain size with advantage. This limit was reached long before one got to the pinhole cap, which opticians supply to condensers for centering purposes.

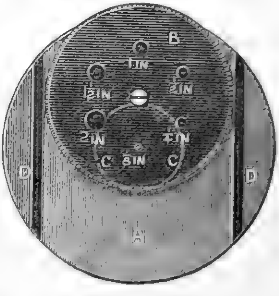
This, then, is the 'sliding stage diaphragm' I have devised, and which I think I may claim as original as it is economic and simple. In my hands it has assuredly improved even the images of objects seen with the fine $\frac{1}{25}$ of Tolles and Zeiss, while with a fine $\frac{1}{2}$ and deep single ocular it has produced such vivid images and shown such detail as almost to suggest the self inquiry of 'What more one wants?' May one trust, then, that this simple bit of apparatus will be a boon to all students of nature through the Microscope? Of course it could be made of various substances. Ebonite suggests itself as appropriate and sightly, while to metal there would be several objections.

In looking to the classes of objects to which this diaphragm would be suitable, those requiring 'resolution' must be at once put on one side, and the advantages looked for in improving the defining power of objectives on the thousand and one objects which interest the microscopist, and these advantages can easily be verified on reticulated structure, and indeed on any delicate tissue apt to be half lost in a flood of light.

Fine as is the image shown by the stage diaphragm in an appropriate object, a *finishing* touch, very slight, to the Iris diaphragm will often bring about a still further perfection of image, which the practical microscopist will not be slow to appreciate."

Bousfield's Rotating Diaphragm-plate.*—Mr. E. C. Bousfield describes a rotating diaphragm-plate, shown in Fig. 123 (reduced size), which he has devised for use close beneath the object on the stage. It consists of a brass plate A, about $\frac{3}{16}$ inch thick, fitting on the stage in the manner of a super-stage by means of two pegs let into holes in the stage itself. A hole C C, about $\frac{3}{4}$ inch in diameter, is bored through the plate, and over this revolves a plate B about 2 inches in diameter, or of such a size as to project beyond the outside of the plate A, and of the central hole. The edge of this plate is milled, and it is about $\frac{1}{16}$ inch thick; it is sunk into the face of plate A just sufficiently to allow of its being turned when the slide is in place. The apertures in this smaller plate vary in size to suit the different sizes of field seen with objectives of different focus. D D are grooves for the usual sliding object-holders.

FIG. 123.



Mr. Bousfield, in view of the fact that diaphragms should always be placed *close under* the object, notes that "Iris" diaphragms (as usually made) fail in this respect, as by the system of construction

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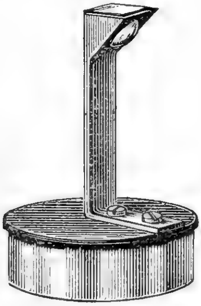
* Engl. Mech., xxxii. (1881) p. 495.

some lateral light is always allowed to pass up beyond the field and thus produce fog.

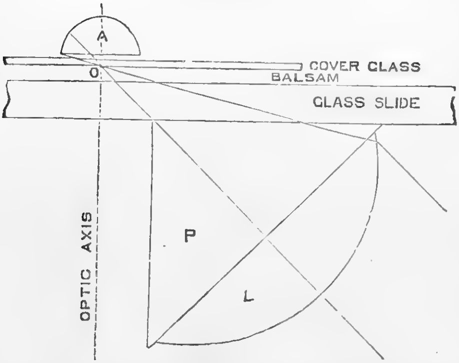
Hyde's Illuminator or Oblique Immersion Condenser.*—The apparatus here shown (Fig. 124) is one of the numerous devices that have been constructed specially for use with immersion objectives having apertures greater than correspond to 180° in air, i. e. greater than the "numerical aperture" 1 (= double the *critical* angle between glass of mean index 1·52 and air, or 82° nearly).

Fig. 124.



It consists of a right-angled prism having a plano-convex lens cemented on the long face, the whole mounted on a metal upright attached to an ordinary substage fitting. The lens is calculated to condense parallel rays to a focus on a balsam-mounted object through a slide of average thickness, with which the illuminator is suitably placed in immersion contact. In this case the ray passing through the axis of the lens without refraction will be incident upon the object at an obliquity of 45° to the optic axis of the Microscope, as shown for the central ray in the diagram of the action (Fig. 125).

Fig. 125.



A is the front lens of an immersion objective in fluid contact with the cover-glass; O the object in balsam; P a right-angled prism in immersion contact with the base of the slide; L a lens designed to focus the illuminating rays on the object O.

For the oblique illumination, as figured, the apparatus must be placed out of the axis of the Microscope. With this obliquity any objective of less aperture than 90° in glass would give a dark field. If placed nearer the axis it is evident that less oblique rays could be used, as the lower half of the lens and prism would then come into action.

As originally made, the device was mounted in a brass plate fitting into the stage opening, but it was found more convenient when placed in the substage with means of varying the degree of eccentricity, upon which depends much of its power as an oblique illuminator.

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* See this Journal, ii. (1879) p. 31.

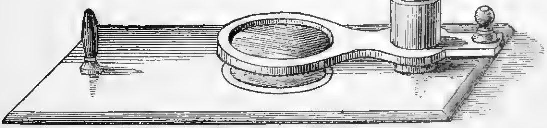
The apparatus was brought from Philadelphia by Colonel G. L. Tupman, R.M.A., to whom we are indebted for the diagram.

High Magnifying Power.—The following will serve to start a column of "Curiosities of Microscopical Optics!" It is not necessary to suppose it to be a hoax, as claims to magnifications not far short of some of those described have previously been made with undoubted seriousness.

"Professor F. G. Fairfield, of New York, has, according to Gaillard's 'Medical Journal,' invented a new objective, giving an increased magnifying power of 49 per cent. It multiplies the power of the Microscope by 7 in diameter and by 49 in area. The visualizing power of the Microscope had heretofore been reckoned to be equal to the showing of an object $\frac{1}{180000}$ of an inch in diameter. That was the limit to which Helmholtz attained. With Tolles' $\frac{1}{75}$-inch, exhibited in the New York Academy of Science two years ago, it was shown that there could be discerned an object $\frac{1}{2500000}$ of an inch in diameter. 'With the $\frac{1}{8}$-inch objective or lens,' said the lecturer, I am able to discern an object $\frac{1}{3000000}$ of an inch in diameter; and if I were to apply the same principle to a $\frac{1}{75}$-inch lens, I should be able to discern an object, making allowance for proper diffusion of light, as minute as $\frac{1}{15000000}$ of an inch in diameter. At that power it would be possible, unless the molecule of albumen be much smaller than it is supposed to be, to discover and demonstrate the molecular constitution of living matter.' The objective invented by Professor Fairfield is composed of three minute lenses in succession. After the rays have passed through the three lenses, formed their image, and crossed, they are then taken up in a field-glass, through a second powerful lens, cross a second time, and a second image is formed from the first. The alleged result is that the penetrating power is very much improved as compared with the ordinary lens, whose power is actually multiplied by more than 49 per cent. The lens is so minute as to be capable of being used only by the aid of the electric light." *

We may again point out that Professor Helmholtz has never asserted that the $\frac{1}{180000}$ inch is the limit of visibility in the Microscope. His researches on this subject referred to the limit to the *power of separating* two portions of an object which are close together.

FIG. 126.



Graham's Compressorium.—Fig. 126 shows this apparatus, which was described, but not figured, at p. 148 of vol. iii. (1880).

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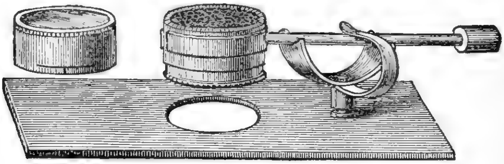
* 'British Medical Journal,' 1881, March 5th, p. 353.

Insect Cage.—This (shown in Fig. 127) is intended for the study of live insects. To one end of a 3 by 1 brass plate is attached an upright, supporting a cross-piece at the top on which rests the stem carrying the cage. This is held in place by a spring, and may be rotated or moved longitudinally by a milled head. The cage is constructed on the same principle as the ordinary live-box, but instead of glass, bobbinet is used in order to confine the insect better and without injury. A cover of glass can be used if preferred. The cage may be rotated in the optic axis of the Microscope in order that the object may be illuminated to the best advantage.

Fig. 127.



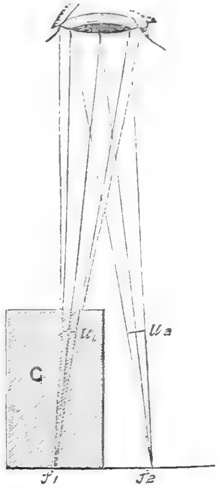
The Essence of Homogeneous Immersion.—With reference to the note at p. 131 it seems to have been supposed that the essence of this kind of immersion objective would have been rested entirely upon the increase of aperture which the immersion fluid renders practicable.

A homogeneous-immersion objective does of course allow of an increase in aperture as compared with a dry objective or a water-immersion objective in the proportion of 1·0 to 1·33 and 1·52—those figures being the refractive indices of the three kinds of objectives,—and the larger apertures so obtained constitute the *practical benefit* to be derived by the investigator from the use of homogeneous-immersion objectives. When, however, we speak of the "essence of homogeneous immersion" it is obvious that the *essence*, in the strict sense of the term, must relate to something which is common to *all* kinds of homogeneous-immersion objectives—not simply to those of high angles only but to low ones also, and the correct use of that term is not affected by the fact that low-angled homogeneous-immersion objectives are not found in practice.

The *essence* of homogeneous-immersion depends therefore on the greater facility which is afforded for correcting objectives of very wide angles; the *practical advantage* is the increase of aperture which can be obtained by the use of a fluid of higher refractive index than water.

Abbe's Apparatus for demonstrating the Increase of Radiation in Media of higher Refractive Index than Air.—We should have added to the description of this apparatus given at p. 343 a note as to the effect of removing the plate B and observing the two fields f_1 and f_2 direct. In this case, of course, the greater brightness is not seen at f_1, but, on the contrary, it looks slightly *less* bright, owing to the greater loss from absorption and reflection in the glass block. Owing to the increase of divergence of the pencil u_1 on its exit from G, the pencil which just fills the pupil of the eye is, *within the glass*, of a *smaller* angle (u_1) than that pencil (u_2) which reaches the eye *direct* from air. Thus the greater intensity of radiation within G is just compensated for by the diminished angles of the pencils which are admitted to the eye ($u_1 : u_2 :: 1 : n$ for narrow-angled pencils).

Fig. 128.



β. Collecting, Mounting and Examining Objects, &c.

Deby's Improved Growing-slide.*—Referring to the growing-slide described at p. 333 of vol. iii., Mr. Deby says that some difficulty seems to have been found in the making of these slides, so that he has devised a still more simple contrivance for obtaining the same results. Take an ordinary glass slip, with a circular hole, say half an inch or more in diameter, in the middle; lay this slip on an ordinary glass slide, not perforated. Then grease the top of the upper or perforated slide just a little way around the circular hole, and join the two slips of glass by means of two rubber rings. The object is then placed on a thin cover-glass, somewhat larger than the hole in the slide; it is then covered by a thin glass cover, $\frac{1}{4}$ inch in diameter; the whole is then turned down and fastened to the slide by the adherence of the grease while the small cover prevents the running of the liquid. The plant or animal under examination finds itself confined in a sort of miniature Ward's case. When not under observation, the growing slide is laid flat in a shallow plate with water just above the line of junction of the two slips of glass, where, by capillarity, it creeps up to the central cell, where evaporation keeps the contained atmosphere in a state of constant and healthy saturation (see Fig. 129).

Fig. 129.

Method for Colouring Infusoria and Anatomical Elements during Life.†—M. A. Certes has endeavoured to find some drug which would stain bodies during life; and he finds that Infusoria placed in a weak solution of chinolin or cyanin are coloured a pale blue, and may continue to live for as many as thirty-six hours; strong solutions are immediately fatal. After being for twenty-four hours in a damp

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* Journ. Quek. Micr. Club, vi. (1880) pp. 166–7.

† Comptes Rendus, xcii. (1881) pp. 424–6.

chamber the white blood-corpuscles of the frog, tinged with cyanin, presented amœboid movements; serum was found to dissolve the cyanin better than water.

The coloration appears to be concentrated around the fat-granules of the protoplasm; it is feeble, not to say nil, in the cilia, the cuticle, and the vacuoles; the nucleus and nucleolus escape completely; this is so far an advantage that it makes the observation of the division of these bodies more easy, and affords a demonstration of the difference in chemical composition between them and the surrounding protoplasm. The whole series of observations are interesting as demonstrating that it is not impossible to colour a living cell.

Double and Treble Staining.*—The process of using dyes of two different colours, so as to differentiate more clearly certain parts of a microscopic section of an organ, is, Dr. W. Stirling considers, of the greatest value, and can be employed with excellent results even by students. Having used various methods for the last three years, he now gives a brief account of those combinations of colours which he has found to be most useful for class purposes, and the organs for which each combination is best suited.

(1) *Osmic Acid and Picrocarmine—Blood of a Newt or Frog.*—Mix a drop of blood with a drop of a 1 per cent. aqueous solution of osmic acid, and allow the slide to stand. This "fixes" the corpuscles without altering their shape. At the end of five minutes remove the excess of osmic acid with blotting-paper, add a drop of solution of picrocarmine and a trace of glycerine to prevent evaporation, and set aside for three or four hours (or even longer, as no overstaining takes place). At the end of this time the nucleus will be found to be stained red, and the perinuclear part homogeneous and yellow.

(2) *Picric Acid and Picrocarmine—Blood of a Newt or Frog.*—Place a drop of blood on a slide, and add a drop of a saturated solution of picric acid; put the slide aside and allow it to remain for five minutes, and at the end of that time, when the acid has "fixed" the corpuscles (that is, has coagulated their contents), the excess of acid should be removed by means of a narrow slip of blotting-paper. A drop of a solution of picrocarmine should now be added, and a trace of glycerine to prevent evaporation, and the preparation set aside for an hour. At the end of that time remove the picrocarmine solution by means of a slip of blotting-paper, and add a drop of Farrant's solution or glycerine, and apply a cover. The preparation may then be examined, when the perinuclear part of some of the corpuscles will be seen to be highly granular and of a deep yellow colour, while the nucleus is stained red. In some of the corpuscles there may also be seen delicate yellow-coloured threads, extending from the nucleus to the envelopes; in others, the perinuclear part remains uniformly homogeneous. This and the above preparation of blood-corpuscles can be preserved in glycerine.

The processes for *Yellow Elastic Tissue*, *Yellow Fibro-Cartilage*, *Fœtal Bone*, and the *Aorta* are also described.

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* Journ. Anat. and Physiol., xv. (1881) pp. 349–54.

(3) *Picrocarmine and Logwood.*—Stain the sections first with picrocarmine, and after staining wash them in water slightly acidulated with acetic acid. Stain them with *dilute logwood* solution till they assume a lilac tint. Wash them, and mount in glycerine or dammar; the great point is to avoid overstaining the sections with the logwood. This method does very well for skin, scalp, developing bone, and the non-striped muscular fibres of the mesentery of the newt.

(4) *Picrocarmine and an Aniline Dye.*—Dr. Stirling has tried a great variety of the aniline dyes, but finds none of them so good, at least for gland tissue, as iodine green; it is used in the form of a 1 per cent. watery solution. Stain the tissue in picrocarmine, wash it in water acidulated with acetic acid, and then stain it in a solution of iodine green. This solution stains rapidly, and care must be taken not to overstain the tissue. Rapidly wash the section in water, and mount it in dammar. The section must not be left too long in spirit before cleaning it with clove-oil, because the spirit dissolves the green dye. Specimens doubly stained in this way have been preserved for many months, and students succeed in the process with the best results. Few methods yield such good results and are so instructive for the purpose of teaching. All preparations stained with iodine green must be mounted in dammar.

(5) *Picrocarmine and Iodine Green—Fœtal Cancellous Bone.*—Stain a section of the cancellated head of a fœtal bone in picrocarmine, and after washing it, stain it with iodine green and mount it in dammar. All the newly formed bone is red, but in the centre of each of the osseous trabeculæ the residue of the calcified cartilage on which bone is deposited is stained green. No method differentiates so clearly this marked difference in the constitution of these trabeculæ. Many of the bone corpuscles are stained green.

Ossifying Cuticular Cartilage, Posterior part of the Tongue, Peyer's Patch, Solitary Glands, Trachea, and *Bronchus* are also dealt with. In the case of the *Skin,* double stain a vertical section preferably from the sole of the foot of a fœtus. The cuticle and superficial layers of the epithelium are yellow, the stratum (rete) Malpighii is green, and one sees most admirably the continuation of these cells into the ducts of the sweat-glands, which are themselves green and form a marked contrast to the red-stained connective tissue of the cutis vera, through which they have to ascend to reach the surface. The outer layer of the grey matter of the *Cerebellum* with Purkinje's cells is, when double stained, red, while the inner or granular layer is green.

(6) *Logwood and Iodine Green* does best for the mucous glands of the tongue (green), while the serous glands take on the logwood stain.

(7) *Eosin and Iodine Green.*—Eosin is used as the ground colour. Stain the tissue in an alcoholic solution of eosin, which will stain it very rapidly, usually in a few seconds. Wash the section thoroughly in water acidulated with acetic or hydrochloric acid (1 per cent.), and then stain it with iodine green. This combination does very well for developing bone and for the cerebellum.

(8) *Eosin and Logwood.*—Here, again, eosin is the ground colour. This combination does very well for the cerebrum. Its general substance becomes stained with the eosin, while the logwood gives the nerve-cells a lilac or logwood tinge.

(9) *Gold Chloride and an Aniline Dye.*—Dr. Stirling corroborates Dr. H. Gibbes' views as to the value of this combination. The tissue must first be impregnated with gold chloride, and then stained with either aniline blue, iodine green, or a red dye such as rosein. The *tail of a young rat*, containing so many different structures, is an excellent material. Remove the skin from the tail, and place pieces one inch long into the juice of a fresh lemon for five minutes, and afterwards wash them to get rid of the acid. The fine tendons swell up under the action of the lemon-juice, and thus permit the more ready access of the gold chloride. Place the tissue for an hour or an hour and a half in a 1 per cent. solution of gold chloride; remove it and wash it thoroughly, and place it in a 25 per cent. solution of formic acid for twenty-four hours, which reduces the gold. During the process of reduction the tissue must be kept in the dark. The osseous tissue has then to be decalcified in the ordinary way, with a mixture of chromic acid and nitric acid. After it is decalcified preserve the tissue in alcohol. Transverse sections of the decalcified tail are made, and they may be stained with a red dye, such as an alcoholic solution of rosein, and afterwards with a watery solution of iodine green; mount them in dammar.

Preserving Confervæ and Desmids.*—The following solution has been found by P. Petit to be the best adapted for preserving the natural green colour of the chlorophyllian Algæ (Confervæ and Desmids), it having occurred to him that success might be attained by applying to Algæ the process made use of in commerce for preserving the green colour of vegetables.

The basis of the solution is "Ripart's fluid,"† and, by the addition of a copper salt, the tendency of that preparation to destroy the chlorophyll is overcome.

	gr.
Camphorated water	50·
Distilled water	50·
Crystallizable acetic acid	0·50
Crystallized chloride of copper	0·20
,, nitrate ,,	0·20

Dissolve and filter.

Preparations made in this liquid have preserved the brilliancy of their green hue, even after a year's exposure to the full daylight. *Spirogyra*, *Ulothrix*, and, above all, Desmids (*Penium Nægeli* and *Micrasterias crenulata*) have thus been preserved in all their freshness.

Preserving Marine Algæ.‡—Mr. C. J. Jones describes the following method which he adopts for preserving the colour of marine algæ.

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* 'Brebissonia,' iii. (1880) p. 92.

† See Cornu and Rivet, 'Des Préparations microscopiques,' Paris, 1872.

‡ 'Northern Microscopist,' i. (1881) pp. 54–6.

The algæ are first washed in fresh water directly they are taken from the sea, to get rid of all sea-salts; they are then floated on to writing-paper, and dried by gentle pressure between sheets of white blotting-paper. When apparently dry, they are put between fresh blotting-paper and packed away in a dry place, where they must be kept perfectly free from the access of light.

When quite dry, cut off the number of pieces required and soak in *old* oil of cloves for a sufficient length of time to render them transparent, keeping them in the dark during the whole time. When soaked sufficiently, take them out of the oil and lay them upon clean white blotting-paper to absorb the excess, and mount in the ordinary way with cold balsam and benzol, on a cold slide, using a cold cover, and the result will be satisfactory. It is the operation of soaking the algæ in turpentine and the mounting in warm balsam that does the mischief, and it should not be forgotten that if the mounted slides are constantly exposed to the light they will bleach in time.

There are two points which should be noted: *old* oil of cloves must be used; the *new* is clear and of a very light yellow colour, while the old is more viscid and of a clear light brown. The other point is in the preparation of the balsam, that used in the foregoing preparations is at least thirteen years old, and most, if not all, the turpentine it originally contained has evaporated from it; it has been solid for years. The method adopted for bringing it into solution is to pour some benzol into the jar in which it is contained, and when sufficient has dissolved it is poured out into the bottle marked balsam and benzol. By this means only a thin layer of balsam is taken out each time, and having been exposed for a long time to the air it has lost the whole of its turpentine.

Soap for Preparing and Cleaning Diatoms.*—Professor Hamilton L. Smith writes as follows:—"Many persons who have faithfully tried the processes recommended in the books find, much to their disgust, that after all the trouble and care there will always be a large amount of flocculent matter, which neither acids nor burning will remove, and which will cause the diatoms to clot together and make the completed mount a rather dirty object to behold. Turning from their own preparations to those of Möller, and others who may have the secret, they know that there is somewhere a knowledge they do not possess and which has not yet crept into the books. And this is true. I was not myself aware of the remedy until long after I wrote the article which the editor of this journal copied from the 'Lens' into his little book entitled 'Diatoms.'

I have made it known to many, but, so far as I am informed, the process I am about to describe has not been published. I do not know whether 'Möller's secret' has leaked out, and so has reached me in the course of my extensive correspondence, for it is not my own invention, and indeed I cannot now remember just when or where it was first breathed to me, for I have known it for some years, but certainly with no 'injunction to secrecy.' I can assure the disgusted

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* Amer. Journ. Micr., v. (1881) pp. 257–8.

student, who finds his beautiful diatoms—after all the acid treatment and all the incineration—yet full of flocculent matter, that there is a royal way to cleanness, and, after all, the good old way, by the use of soap! In fact, the use of this common and too much neglected article will produce astonishing changes in cleaning up the diatoms, as well as in cleansing dirty linen. I will describe what I did yesterday—the whole during one evening, and in fact, except for the waiting for the diatoms to settle, all the process would not occupy over ten minutes. I received a gathering of marine diatoms from the Hawaiian Islands, enclosed in a joint of bamboo instead of the usual vial. They were dried and matted, but the gathering was rich in the well-known Sandwich Island forms, so characteristic that I could have told the locality if I had not already known.

I put the dried material, such as it was, into a large test tube, and covered it well with nitric acid and left it for an hour (the time is not material). After this I boiled it, adding a little more acid, and, dropping in two small bits of bichromate of potassa, again boiled for a minute or two. The tube was now filled with rain water, and the whole mixed by inverting, &c. As soon as the mass (flocculent enough) had settled, the discoloured and acid water was poured off, and the tube was again filled with rain water (it is better to use soft water). After settling, the water was again poured off, and the deposit once more washed. So far this is the old method, which generally ends here, only washing out as best one can the lighter forms and broken frustules. A preparation made at this stage, marked (1) on the slide sent herewith, showed plenty of diatoms, principally *Synedra robusta* and *Rhabdonema mirificum*, but also any amount of the flocculent matter—the bane of diatom preparers, and which, from presence still of organic matter, browned in burning; a subsequent washing somewhat improved this—see specimen marked (2). Pouring off the supernatant water, and adding a little clean soft water, I now put into the tube a bit of common yellow soap, size of a pea, and again boiled the deposit for a minute or two, after which the tube was filled with clean rain water. Some fifteen or twenty minutes after, the yet milky fluid was poured off; it contained but few and very minute diatoms, which one can save, if so disposed, by keeping the poured-off fluid for a longer time. The tube, with a heavy deposit at bottom, was again filled with rain water and shaken, and now a peculiar brilliant sparkling and play of colours showed that the flocculent matter was gone, and only clean diatoms, sponge spicules, and possibly some sand remained. Specimen marked (3) shows appearance at this stage, and that marked (4) after one more washing. Finally, distilled water and alcohol was added; and after this washing, pouring off all the finer forms which remained in suspension after five minutes, and which were saved with those of the other washings, little else remained except clean diatoms, as shown on the finished slide sent herewith.

If, after this, any one exhibits a slide of diatoms full of flocculent and dirty deposit, peculiar to the old methods of treatment (unless, indeed, the original gathering had been an exceptionally clean one), we can only say, as in Miss Edgeworth's nursery story, 'What! no soap?'"

A caution was subsequently given,* which well deserves the attention of those who use soap. Many of the brands of soap contain notable quantities of silica in various forms. Even the fine toilet soaps contain it, the addition having been made for the purpose of increasing their detersive power; while to many of the more common kinds kaolin, silica, &c., are added merely for the purpose of increasing the weight. Therefore, in using soap, care must be taken not to use such as will introduce insoluble matter and even diatoms foreign to the original gathering.

It will be remembered that we have already given † an abstract of an article by Dr. H. Stolterfoth, describing his method of using soap for cleaning diatoms.

Mr. E. H. Griffiths endorses ‡ the use of soap with, if necessary, the subsequent use of nitric acid and carbonate of potash to bleach.

Mr. F. Kitton has also tried it § on a subpeat deposit and a recent fresh-water gathering from New Zealand, both of which, however, required acid treatment before being sufficiently clear for mounting. With Peruvian guano he found that the soap very much assisted in getting rid of a quantity of colouring matter, and materially reduced the amount of crude material. After pouring off all that did not subside in one hour he again boiled in soap and water, which further reduced the quantity, but the residue was totally unfit for mounting until further cleansed with nitric acid and chlorate of potash, and a final wash with liquor ammoniæ. On the marine deposits such as those from Virginia, California, Barbadoes, &c., soap seems to have but little if any effect.

To those who may be desirous of trying the soap process the following hints may be useful:—

1st. Carefully avoid hard water.

2nd. Use the best yellow soap (the ordinary soap often contains oil).

3rd. If soap is used after the acid, remove all traces of the latter with soft or distilled water.

4th. Dissolve the soap in the water and pour it on the material so as to make sure that no portion of it remains undissolved.

The soap process does not, in Mr. Kitton's opinion, possess any advantage over liquor ammoniæ in eliminating flocculent matter. The preliminary boiling in soap and water, by getting rid of a portion of the non-diatomaceous material, no doubt reduces the quantity of acid required, but it will not supersede the use of it.

Sullivant's Mechanical Fingers.||—Mr. J. Sullivant, of Ohio, has constructed mechanical fingers in two ways, which may be followed by any one desiring such an appliance and having a stage forceps only, or still better, a forceps and a nose-piece also.

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* Amer. Journ. Micr., vi. (1881) p. 15.

† See this Journal, iii. (1880) p. 1034.

‡ Amer. Mon. Micr. Journ., ii. § Sci.-Gossip, 1881. pp. 102-3.

|| Amer. Mon. Micr. Journ., i. (1880) p. 186.

1. By taking a strip of pine wood, half an inch thick and of suitable length and breadth, and giving it a suitable shape, making a hole in the larger end of such size, that when lined with a bit of cloth, it fits tightly on and over the nose of an inch objective. In the smaller end another hole is to be made, into which a slightly tapering cork is pressed from above, in order to carry the forceps. Having fastened a bristle into the jaw of the stage-forceps by means of a drop of glue, and made a small hole for a guide, the shank of the forceps is forced into the cork and fastened in position with sealing-wax, and the finger is complete, with no expense but an hour's labour.

2. With still less labour, the nose-piece can be substituted for the above wooden carrier, screwing the cork into the nose-piece instead of the extra objective, and attaching the forceps as before.

In either case, the elasticity of the cork holds it in place with sufficient firmness to admit of its being rotated with finger and thumb, so as to move the point of the forceps with the bristle to the right or left as may be desired. The lifting of the object is done by means of the joint in the forceps.

Although these fingers may not be as perfect as those of more costly construction, yet combining as they do all movements essential to any finger, they may, the author considers, be used in an emergency, and in skilful hands will be found capable of effective work.

Mounting with Glycerin-jelly.*— Glycerin-jelly has long been known as a mounting medium, but most persons have found some difficulty in its use. The precipitation of balsam by all watery objects, especially aquatic insects and fresh-water algæ, induced Mr. W. H. Seaman to devise the following method of manipulation, by which glycerin-jelly may be used with great rapidity, avoiding the tedious preliminary preparation necessary for balsam :—

The jelly is made by dissolving transparent isinglass in sufficient water, so that it makes a stiff jelly when at the ordinary working temperature of the room where the slides are mounted, add one-tenth as much good glycerin and a little solution of borax, carbolic acid, or camphor-water. The mixture should be well filtered while hot through washed muslin or other fabric, as it will not run through the usual filter-paper, and the subsequent addition of a little alcohol improves its working. Objects, if perfectly clean, may be transferred at once from water to this medium, which should be slightly warmed before using, if not perfectly fluid. The cover is adjusted and the slide put away until a number have accumulated. The cover should not be pressed down too hard, and a liberal amount of jelly used to allow for shrinkage in drying. The slides may be finished as soon as the jelly has set, or they may be left for several days. If air bubbles are entangled they will usually escape while drying, or they may be driven out by warming the slide a little. When ready to finish the slides, take them to a water cooler and let the ice-cold water drip over them, while with a camel's-hair brush, rather stiff, all the superfluous jelly may be readily brushed away by the aid of the flowing

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* Amer. Mon. Micr. Journ., ii. (1881) pp. 4–5.

water, which keeps the jelly under the cover hard. The slides are then dried with a towel or blotter, and finished with a balsam ring or any other cement desired.

The advantages of this method are that it obviates the necessity of the previous preparation of cells for objects of considerable thickness, and it seems to present most of the advantages of a fluid mount without its difficulties. If the slide is properly dried before finishing with balsam, no cloudiness appears, and the slide cannot be distinguished by inspection from a balsam mount, while there is much less distortion, loss of colour, &c., in the jelly than in the balsam solutions usually employed. Mr. Seaman has found no reason in ten years' experience to doubt that slides mounted in this way will be permanent.

Mounting Starches.*—The Editors of 'The Microscope'† describe their method of preserving starches as follows:—

"It is necessary first to have some aniline blue staining fluid, which we make after the formula given by Beale:—

Soluble aniline blue	$\frac{1}{2}$ grain.
Distilled water	1 ounce.
Alcohol	25 drops.

A mixture is made of equal parts of glycerine and water, to which is added a very little acetic acid, only two or three drops to the ounce.

To this mixture of slightly acidulated dilute glycerine is added the aniline blue staining fluid until the whole mixture is of a decided blue colour.

A drop of this mixture is placed on a glass slide and some of the starch to be mounted is dusted over the top. This dusting can be done to the very best advantage by touching the starch with a camel's-hair brush, and then slightly shaking the brush over the drop of coloured glycerine.

The starch soon sinks in the mixture, and the cover is applied. This method of dusting the starch is much better than stirring it in the mixture with a fine needle, which almost invariably results in an admixture of air.

After the cover is applied it is pressed down quite firmly against the slide, and all excess of the glycerine carefully removed. The slide is then transferred to the turntable, and a thin layer of dammar or balsam in benzole placed around the border of the cover. This soon hardens, and in a day or two we can finish with the white zinc or Brunswick black or other cements.

The effect of thus mounting the grains of starch is this:—the grains themselves have not taken the staining in the least, neither will they ever take it; they retain their natural appearance, surrounded everywhere by the blue glycerine, and the effect is most beautiful.

Specimens are in the Editor's possession that were mounted over a year ago in this way, and they are as perfect as the day they were prepared."

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* 'The Microscope,' i. (1881) pp. 13–14.

† See this Journal, *infra*, p. 546.

Another plan is suggested * as an alternative to the ordinary one of placing a small quantity on the slide and then applying the balsam. Pour into a test-tube a sufficient quantity of Canada balsam to mount as many slides as may be required, and heat over the flame of a spirit lamp. When the balsam becomes thin, dredge into it through muslin the starch to be mounted. The air-bubbles must be burst either by again heating the balsam, or by diluting it with turpentine. The starch may then be mounted by taking up a small quantity with a dipping tube, and placing upon a glass slip, and covering with a thin circle or square previously warmed.

Mounting Desmids.†—Dr. M. C. Cooke, in dealing with the subject of mounting desmids for the Microscope, considers that the preservation of the endochrome and its colour is a matter of minor importance. For scientific purposes the empty frond is often of superior value to one filled with endochrome, as it permits the punctæ or markings of the segments to be seen, which are obliterated whilst the endochrome remains, and in the genus *Cosmarium* this is of greater importance than ever.

For the study of the endochrome alone its presence is of course most important; but this can be done, and drawings made from the plant in the living state, and if specimens can be mounted with the endochrome unchanged and uncontracted, so much the better, but no method has yet proved entirely satisfactory. Dr. Cooke kept some slides for twelve years mounted in silicates of potash and soda, but half of them deliquesced. Mr. Wills, however, kept slides much longer by simply using the water in which the Desmids were collected and never leaving them exposed to the daylight.

One great difficulty in mounting objects with such thin and delicate cell-walls as desmids is to employ a medium of no greater density than the cell-contents. If a denser medium, such as glycerine, be used, the endochrome immediately contracts, and never expands again as before. Water, or water containing a little camphor, is of equal density, and no change can be detected.

After all, the preservation of the endochrome is of less importance than the perfect contour of the cell. If there is any contraction or collapse, the objects are useless. Supposing, therefore, that there is no necessity to preserve the endochrome, there is another feature to remember besides the preservation of contour, and that is, that the medium employed should not render the delicate cell-walls so transparent as to become ultimately invisible. In simple water Dr. Cooke found no difficulty in discerning the structure of the cell-walls after a period of not less than twelve years. So much cannot be said for glycerine. Empty fronds, both of desmids and *Volvox*, stained of various colours, exhibit all the details in an unexceptionable manner.

Wax for Dry-mounting Opaque Objects.‡—Mr. H. J. Roper uses mahogany slides, 3 inches by 1 inch, with central circular cell

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* Sci.-Gossip, 1881, p. 88.

† Journ. Quek. Micr. Club, vi. (1881) pp. 203-11 (4 pls.).

‡ Ibid., pp. 193–5.

pierced partially through the slide, leaving a "floor" of the wood, with sheets of wax, such as is used for making wax flowers (green and white).

To mount as an opaque object, say a portion of leaf with a parasitic fungus on it, cut a square, about an inch across, of the green wax, and lay it over the aperture in the slide; press it firmly down, and it will line the whole cell smoothly, and leave a margin of wax projecting round the upper surface. Having made sure that the leaf has no foreign matter on it, cut it so as to nicely fit the sunken cell, now lined with wax (if preferred leaving the wax showing all round), and a very slight pressure with the forefinger will ensure its adherence to the floor of wax, without in any way damaging the leaf or fungus; place the covering glass over the wax cell and press it firmly but gently down, then remove with the penknife all superfluous wax close to the edges of the covering glass; place over this the covering paper, not applying too much moisture round the central aperture, and the slide is complete.

It will sometimes happen that a slide is bored so deeply that it is necessary for the convenient illumination of the object that something more than one thickness of wax should be placed in the cell, so as to bring the object nearer to the covering glass; this can be taken advantage of to produce a very pretty effect. Before proceeding to line the cell with the wax, place an ordinary wafer in the bottom of it, moistening only the *lower* surface, choosing one, say, of a deep red colour; place over this a square of the white wax, which is always semi-transparent, and the result will be a delicate pink ground, well calculated to show up to advantage many opaque objects; other coloured wafers will produce at pleasure grounds of different tints, quite destitute of "glare" or "reflection," and soft and pleasing to the eye.

The advantages of this method, which is not new, except in slight but not unimportant modifications, are the unfailing certainty of the process, its celerity, total independence of turntables and varnishes, the lightness of the slides, the non-liability to breakage (for there is nothing frangible but the covering glass), and last, but not least, the permanence of the preparation. As to Professor Hamilton Smith's objection to wax cells on account of the covering glass becoming covered inside with a dew-like deposit, Mr. Roper has noticed this occasionally in specimens mounted on *glass* slides, but very rarely (not perhaps 1 per cent.) when mounted on *wooden* ones; and then no doubt the wax was used when too new, sufficient time not having been allowed for its volatile properties to evaporate; it is probable, too, that the wood itself may absorb the slight moisture which, in the case of the glass, can obtain no other refuge than the covering glass; at any rate, speaking from his own experience, he has found no inconvenience on this score, after mounting many hundreds of slides, extending over several years. The result of this very simple, quick, and easy process is, that the object is enclosed in a cell at once air-tight and water-tight, the adhesion of the wax to the wood, and the covering glass to the wax, strengthened by the adhesive cover paper, ensuring immunity from damp, while he has never known an instance in which any object was in the least affected by contact with the wax itself.

Wax Cells with White Zinc Cement for Fluid Mounts.—Mr. W. H. Walmsley, of Philadelphia, points out that while much has been written regarding the use of wax cells for dry mounts, their eminent adaptability for fluid mounts has been strangely overlooked. His own use of them for this purpose has extended over a considerable period of time, and has given great satisfaction. In the matter of economy, ease of preparation, and durability he considers the method adopted of considerable value. His chief reliance for the permanency of the cells rests upon the use of white zinc cement for coating the wax, the latter being mainly used for making the cells of various depths. Thirteen years' use of the white zinc cement, during which time he has prepared thousands of slides, has satisfied him of its entire permanence, while it is the most easily used of any cement, and its appearance is elegant on a finished slide. The only defect is that it turns yellow in time.

A ring of the cement is first made upon the slide with the turntable. The wax ring is then added, and over the same successive coats of the cement are applied, allowing each to dry before another is added. After the last coat has been applied and the cell allowed to dry for some time, the cement becoming hard in about a day, or even less time, a thin coat of the cement is now applied, after which the cell is filled with the mounting fluid and the object is spread out and arranged properly in the cell. A thin glass cover must then be made to cover the cell in the usual manner, expelling the air, and it will adhere to the fresh cement all around. A spring clip is attached, the slide washed with clean water, using a camel's-hair pencil, then dried with a soft towel, when after a time another ring of the cement may be run around the cell, and the cell ornamented with coloured rings. The fluids used have been glycerine both pure and diluted, carbolic acid water, and Goadby's fluid.

Mr. Walmsley recently forwarded to the Society several slides which he had prepared and which appeared to be in every way excellent,* and he has communicated the formula which he now uses for preparing the cement as follows:—

One part (by weight) of mastic (tears) to 3 parts of gum dammar, dissolved in benzol. To 3 pints of this solution (about the consistency of cream) add 1 lb. of pure French oxide of zinc, ground in a small portion of linseed oil, and stir thoroughly. As the zinc will settle by standing it should be stirred every time it is used, and if it becomes too thick to flow readily, add a little benzol.

How to make Wax Cells.†—The wax cell seems to be in the peculiar position that, while some—even its originator—have discarded it, others declare that it is a valuable means of mounting objects. Dr. F. L. Bardeen, of Rochester, N.Y., writes as follows.

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* See this Journal, *ante*, p. 147.

† Amer. Journ. Micr., vi. (1881) p. 48 (4 figs.). See Engl. Mech., xxxiii. (1881) p. 158.

"In view of its early brilliant promise, and present measure of success, would it not be well to try still further to rear it into full maturity? I now have about two dozen cells over a year old which are as good as when put up—not a flaw or sign whatever of moisture or condensation on the cover—no cracking, or cleaving from the slide. I have also sent at least three times as many to correspondents, mounted in the same way and at the same time, and as yet I have to hear of any going astray.

I do not know that there is anything essentially new in my method, or anything that others have not done; still one or two points I have not seen mentioned.

1st. I try to make the cell perfectly dry. This I do by *melting the wax as I make the cell*, also by drying the object and cover-glass and mounting as quickly as possible.

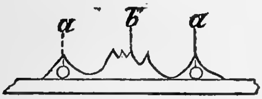
2nd. I hermetically seal the cell.

Concerning the first, I melt the wax as it is put on the slide, and also again as I shape it with the glass rod. I consider the melting as a very essential step in the process, as will be seen by the "sputtering" when melted and when remelted by the glass rod. The sputtering indicates moisture. The details are as follows:—

For deep cells I use brass rings to suit $\frac{5}{8}$-inch covers; for shallow cells one or two layers of tin-foil rings cut out with gun-punches. First cut from thin wax sheets two or three disks, and place on the slide—on the discs, place the ring (heated). Heat the slide till the wax melts. Some of it will run under the ring and form a wall outside the ring. Press the ring to the slide. Before it solidifies put it on a turntable and centre it. This will necessitate quick work on the non-self-centering table. It is best to prepare a number of slides thus far before the next step is taken.

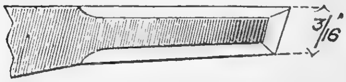
The cell is now half or two-thirds full, and level. Next take a glass rod 6 or 8 inches long and $\frac{3}{8}$ inch in diameter, round one end off in an alcohol flame, heat it hot enough to melt wax, and with the slide on the turntable make a depression all round the cell next the ring. This remelting and stirring as the table revolves, has the effect to still further displace any remaining air. Keep the table revolving until the rod is cold and the wax solid. The cell has now a raised ridge of wax on and at the inner edge of the ring, and a raised central part on which the object is to be mounted. (Fig. 130.)

FIG. 130.



Vertical section of cell. *a a*, cross section of ring; *b*, central portion.

FIG. 131.



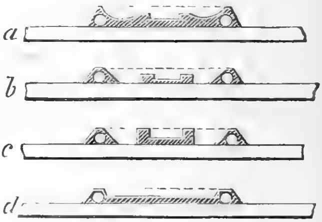
Bevelled turning tool, actual width at point $\frac{3}{16}$ inch.

Now with a turning tool (Fig. 131) made on the end of a small thin flat file or a similar piece of metal, turn the cell down as in Fig. 132. If the form of the object to be mounted permits, it can be fastened in place by simply touching the wax with the point of a hot wire. If the object is like globular sand or Polycystina, liable to roll about, a depression can be turned in the central part with slight containing walls. (Fig. 133, *a*, *b*, *c*.) If desired the central portion can be made as high as the outside, so that the cover will touch it when in place (*c*). If more room is needed, the whole cell may be made as at *d*.

Fig. 132.

Central portion levelled off, also part over ring for cover.

Fig. 133.



I put the cover on as follows: Heat it enough to drive off all moisture, but not hot enough to melt the wax; lay it on the cell—retain it with a spring clip of *slight* pressure, and then hold it over the top of a lighted kerosene lamp just an instant. The pressure of the clip forces the cover into the melted wax and the cell is hermetically sealed.

Trim off on the turntable any surplus wax on the cover of the outside of the cell, and clean with a bit of cloth folded over the end of a small wedge-shaped piece of wood and dipped in alcohol.

Coat the cells and outer edge of the covers with Walmsley's zinc cement *first*, and put on black or coloured rings *after* it is dry. Cells that "run in"—at least, some of them—have had the Brunswick black put on first. This is wrong, for the turpentine is very penetrating, and should not be used until the zinc cement is quite dry.

This method gives all the beauty and mechanical perfection of lathe-work, and if due precaution is had in regard to the essential steps, will give, I believe, the best cell for opaque mounting."

Gutta-percha Cells.[*]—Dr. Phin has no faith in the durability of gutta-percha. Every specimen that he has had an opportunity of watching has become granular and brittle after a time. The finishing ring of cement which Professor Smith regards as unnecessary,[†] he considers the salvation of the cells. The gutta-percha ring, if unprotected, will, after a time, become a mere mass of loosely adherent grains. If, however, these grains be held together with shellac or some other varnish or cement, the cell may last a long time.

Apertures in Opaque Mountings.[‡]—Mr. C. C. Merriman recommends that a small opening should be left into the cells of opaque mountings, and gives the following directions for making it.

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[*] Amer. Journ. Micr., v. (1880) p. 229.

[†] See this Journal, iii. (1880) p. 863.

[‡] Amer. Journ. Micr., v. (1880) p. 253.

Whatever may be the material of which the cell is made, whether cement, or curtain ring, or hard rubber, file a little notch on the top of it, and on what will be the lower side of the slide, with a thin dentist's file, and large enough to lay a pin in the opening. Then, when the object is secured in the cell, moisten the rim of it, except in the notch, with Canada balsam, and apply the thin glass cover. After a day or two, balsam of the thickness of common syrup may be applied around the edge in such quantity, more or less, as one may fancy, care being taken to avoid the minute aperture. Or, if the balsam should happen by accident to run into the opening, it may be easily drawn out with a pin or needle applied a few times. With the point of a knife on the turntable, first push off any balsam that may be on the cover-glass, then gradually work it up on the slide until the edge of the mounting is a true slope or curve as may be desired.

Mr. Merriman uses for his own opaque mountings, cells made of bleached shellac cement and thoroughly dried. They are translucent, and therefore well adapted for the parabolic reflectors. The balsam in this case forms a beautiful finish, and there is no difficulty in applying it without interfering with the aperture. He does not regard wax cells as safe to use with any mountings, without first being covered with some cement, such as liquid marine glue, or gold size and dammar. If used for opaque mountings the notch should be cut in them before being covered with cement.

This device of leaving a minute aperture in the cells of opaque mountings has been tested for the past three years, and there has not been a failure in a single case that was owing to the mounting, while in hermetically closed cells there would be haziness, or the running of cement, or some trouble after a time with nearly half the specimens.

Copal Varnish.*—Mr. Deby finds this varnish dries very rapidly if slightly heated, or even if placed on a previously warmed slide. Dr. Van Heurck, of Antwerp, was the first to use it. The varnish to be used is what is called the "pale copal," and its consistency ought to be that of oil. It is much pleasanter to use than Canada balsam, does not make bubbles, and its refractive index is not very different from that of balsam, and does not interfere with the resolution of diatom markings. He has lately made many preparations in copal, dispensing with the cover-glass altogether. The drop of copal is placed on the diatoms and heated lightly over the spirit lamp. It soon takes the consistency of amber, and is hard enough to sustain wiping and brushing with a soft brush with impunity. The optical aberrations produced by the cover-glass are thus done away with.

Test for Illumination.†—Dr. Carl Seiler recommends blood-corpuscles as the best test for proper illumination. He says:—

"In arranging our illuminating apparatus, we must have something to judge of the quality of the light as it passes through the Microscope; and it will be found that there is no better test than

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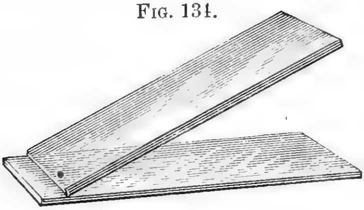
* Journ. Quek. Micr. Club, vi. (1880) p. 167.

† 'Compendium of Microscopical Technology,' pp 14, 15, 17.

a slide of blood, prepared in the following manner.* Take a clean 1 × 3 glass slide, and place near one end of it a drop of fresh blood obtained from the prick of a needle in the finger. Then take another slide with a ground edge, and place its edge into the drop of blood, inclining the second slide until it stands at an angle of about forty-five degrees towards the first one, and draw it quickly but evenly across the first slide (Fig. 134). The result will be that the blood-corpuscles are spread evenly upon the slide, in one layer only, thus giving an excellent view of their outline. The blood-corpuscles being lenticular bodies, with depressed centres, act like so many little lenses of glass, and show diffraction rings if the light is not properly arranged. It will, therefore, be seen that a slide prepared in this manner forms one of the best, if not *the* best, tests for illumination, as well as for flatness of field."

FIG. 134.



The author then describes the arrangement of lamp, bull's-eye condenser, concave mirror, and centering sub-stage condenser.

"When properly illuminated, the blood-corpuscles should appear as slightly olive-coloured disks, with a fine but intensely black outline, and on changing the focus there should appear a spot in the centre. In order to fully appreciate the importance of each one of the parts of the illuminating apparatus, and the necessity of having them in their proper position, let the student first remove the bull's-eye and let the light of the lamp alone fall upon the concave mirror, without change in anything else. He will then see that the outline of the blood-disks is much less sharply defined, and that there is a suspicion of another outline within the outer one. Let him then move the mirror bar slightly to the right or left of the median line, and he will find that this second outline will be more marked and a third one will be faintly seen, while the true margin of the corpuscle is far from being sharp. Let him, finally, remove the substage condenser from its proper position, or throw it out of centre, or take it off altogether, and he will find the blood-disks filled with rings and with a bright spot in the centre."

Microscopical Examination of Blood in the Diagnosis of Disease.†—For the purpose of these investigations, M. Hayem recommends the use of a cell thus constructed: a thick plane glass slide has a disk made on it of about 4 mm. in diameter; the rest of the slide is silvered; a small drop of blood is placed on the disk and is covered by a thin cover-glass, so that a layer of uniform thickness is obtained. A little saliva placed round the edge will prevent any evaporation.

When blood is treated with a mixture of 200 grammes of distilled water, one gramme of pure chloride of sodium, five grammes of sulphate

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* The author describes himself as being indebted to Dr. J. J. Woodward for this plan of making an even blood slide.

† Comptes Rendus, xcii. (1881) p. 89.

of sodium, and half a gramme of pure bichloride of mercury, the blood-corpuscles are separately isolated and distinguished from the other constituents. The fibrine then breaks up into two distinct groups.

Perfectly normal blood, thus treated, shows the following reactions: At the moment when it coagulates it is traversed by a very delicate network of filaments. If at the moment of coagulation a reticulum of thick fibrillæ is seen, we may be sure that we have indications of an inflammatory lesion, and the modifications in the processes of coagulation are due to the extent and intensity of the inflammation. Pyrexia is not accompanied by any appreciable modification of the fibrine; but when fevers are complicated by inflammatory processes there are such modifications. In small-pox they only appear with the suppurating fever; in scarlet-fever and scarlatina the fibrine only augments at the period of desquamation. So again, in typhoid and intermittent fevers the so-called phlegmatic characters only appear when the disease is complicated by inflammation.

When cachectic conditions are not the results of chronic diseases, which bring about inflammatory lesions, the reticulum of the pure blood generally remains invisible, or is obscure, notwithstanding the unusual abundance of hæmatoblasts. Examination by the aid of the solution already described, shows, however, that the fibrine is allied; in advanced cases one often observes the so-called "plaques cachectiques," due to the infiltration of the hæmatoblasts by a finely granular substance, which points to a qualitative change in the characters of the fibrine.

Diatoms as Test Objects.[*]—L. Dippel publishes the result of observations on the value of certain diatoms as test objects for the Microscope, accompanied by exact measurements of the number of striæ.

The various forms of *Navicula rhomboides* are first discussed. The largest forms, called by the author var. *Lewisiana* (but quite distinct from the true and very interesting *N. Lewisiana*) has from 22 to 24 transverse striæ in 0·01 mm.; the ordinary *N. rhomboides* has 28 to 30; and the var. *saxonica* (*N. crassinervia* Breb.) from 33 to 35 in 0·01 mm.

The true *Grammatophora subtilissima* Bailey occurs but rarely as a test object, and has 34–36 transverse striæ per 0·01 mm. *G. macilenta* W. Sm., which is usually supplied for it, has 25–28; *G. oceanica* Ehbg. 21–22; and *G. marina* 14–16 per 0·01 mm. The author describes *G. islandica* Ehbg. with 10–12; *G. serpentina*, with 17–18 transverse striæ per 0·01 mm.; the double structure of *G. gibberula;* and *G. robusta* Dippel, a new species with 14–16 transverse striæ per 0·01 mm. *G. tropica* Kg., to which *G. marina* Dippel also belongs, has 13·5–15·5 transverse striæ per 0·01 mm.; the true *G. marina* Lyngbye has 20·5–21. *G. marina* W. Sm. is one of the numerous intermediate forms between *G. tropica* Kg. and *G. marina* Lyngbye.

Nitzschia curvula has 35–36, *N. sigmatella* 26, and *N. sigma* 20–22 transverse striæ per 0·01 mm.

Drawings are given of all the forms described. It may be stated that all the drawings in Kützing's 'Bacillarieæ' are magnified only from 255 to 260, and not, as stated, 420 times.

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[*] Zeitschr. f. Mikroskopie, ii. (1880) (4 pls.).

Examination of Metalliferous Clays.—Mr. M. Atwood, in a paper on the clays in the Comstock lode read before the San Francisco Microscopical Society, describes as follows the method of separating and examining the gold-bearing fragments :—

"The way in which I made the examination of the clays was, first, to place them in a porcelain dish, pouring hot water over and keeping them in the water for several hours, stirring occasionally till all the particles that would dissolve were taken up by the water. Afterwards I emptied the contents of the porcelain dish into a batéa, allowing everything that was dissolved to float away. By the batéa the pyritic matter and other heavy bodies were separated from the rest of the coarser, rounded, and lighter fragments of vein stuff and country rock. The pyritic matter is then tested for gold, silver, and tellurium, and also a microscopic examination of it is made under water. The fragments of country rock and vein stuff are then washed again, using a brush to rid them of any clay that might still adhere to them. After drying, they are put into a separator having sieves with 30, 50, and 100 holes to the linear inch, a uniform size enabling me to examine them better with the Microscope. The fragments that pass through the sieve having 100 holes I place in a small cell, fastened on the glass slide and filled with water, which I cover with thin glass. The shapes of the fragments are seen much better in this way, since, by slightly moving the thin glass cover, they can be made to turn and exhibit their forms in different directions."

Microscopic Tests for Poisons.[*]—Professor Rossbach has published, in the Vienna 'Klinische Wochenschrift,' some remarkably delicate tests for the presence of poisons when they are in too minute quantities to answer to any chemical tests.

As small animals, like frogs, mice, &c., are known to be very susceptible to the action of certain of the poisonous alkaloids, this fact is taken advantage of, and very weak solutions introduced into their circulation. Delicate as the tests are as applied to frogs, &c., Professor Rossbach gives far more delicate ones. A drop of water, containing infusoria, is placed on a glass slide and examined uncovered. The infusoria are examined carefully as to size, form, colour, &c.; then a drop of the solution is placed just at the edge of the fluid containing the infusoria. If organic poisons be present the infusoria are instantly destroyed, becoming a formless sediment. He says: "If a drop of water containing infusoria and weighing ·001 grain be used as a test, the quantity of strychnine required to cause remarkable changes will be ·00000006 of a grain. In this way $\frac{1}{15000000}$ of a grain of atropine can be detected." Thus, if the stomach of a person poisoned by strychnia contains a litre of fluid and only $\frac{3}{4}$ of a grain of the alkaloid, a single drop of this fluid will contain forty times as much strychnine as is necessary for the test.

Fine Rulings.—We recently referred[†] to "Fasoldt's Test Plate," which it was then claimed contained lines ruled at the rate of 1,000,000 to the inch.

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[*] 'The Microscope,' i. (1881) p. 22.

[†] See this Journal, iii. (1880) p. 891.

Dr. R. H. Ward, of Troy, N.Y., writes upon the subject as follows: *—

"In speaking of the modern microscopic rulings on glass, which have been regarded with so great and deserved an interest by all physicists, one cannot be too careful to discriminate fully between those that are known to be ruled and those whose ruling has been attempted but not yet demonstrated. It is self-evident that, in attempting to rule lines 5,000,000 to the inch, a band may be produced which does not consist of lines of that degree of fineness. There is no difficulty in arranging a machine to draw lines, theoretically, of any required degree of closeness. The register of a ruling engine can be so arranged and subdivided as to indicate a spacing at the ruling point of one ten-millionth of an inch as easily almost as of one-tenth of an inch; but it may well be doubted whether such fine motion is actually imparted to the diamond point, or could be recorded upon the surface of the glass. It is becoming common to hear the higher bands of Mr. Fasoldt, claiming up to 10,000,000 lines to the inch, spoken of as actually ruled, and only waiting an objective to reveal them. Such an error, made inadvertently by persons who would avoid it by a little reflection, as made in the last number of one of the most popular microscopical journals, gives a lasting as well as erroneous impression to non-scientific persons. Mr. Fasoldt's rulings are certainly remarkable, and the lower bands are ruled with great success; but how far up the scale they continue to be ruled as distinct lines is certainly at this time an undecided question."

Journal for Physical and Biological Instruments.—The 'Zeitschrift für Instrumentenkunde, Organ für Mittheilungen aus dem gesammten Gebiete der wissenschaftlichen Technik' † is a new journal, of large octavo size, devoted to instruments used in physical and biological science. The list of editors is headed by Professor E. Abbe, of Jena, the editor in chief being Dr. Georg Schwirkus. The journal occupies a new and important field, and will be of value to microscopists, as it contains a number of articles on microscopical and accessory instruments. Amongst the articles which have already appeared may be mentioned two on the construction and examination of micrometer screws, and on the illumination of micrometrical apparatus in Telescopes and Microscopes.

New Microscopical Journal.—A new illustrated bi-monthly Journal has appeared at Detroit, U.S.A., under the title of 'The Microscope and its Relation to Medicine and Pharmacy.' It is edited by Charles H. Stowell, M.D., Assistant Professor of Physiology and Histology, and Louisa R. Stowell, M.S., Assistant in Microscopical Botany in the University of Michigan.

The first number consists of thirty-two pages, with seven woodcuts, and contains amongst others the following articles:—"Ipecacuanha, its Structure and Adulterations;" "Membranous Dysmenorrhœa,

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* Amer. Natural., xv. (1881) p. 259.

† 8vo., Berlin, 1881.

or False Mole;" "How to Mount the Starches;" eleven pages of "Editorial Abstracts" and "Selections," with a column of "Items" (which includes some medical "Facetiæ") and Reviews.

Seiler's Compendium of Microscopical Technology.*—The author of this book is Dr. Carl Seiler, late Director of the Microscopical and Biological section of the Academy of Natural Sciences of Philadelphia. The various chapters deal with (1) The Microscope and how to use it; (2) Preparation of animal tissues; (3) Cutting sections; (4) Staining of tissues; (5) Injecting the vascular system; (6) Mounting and finishing of specimens; (7) The preparation of vegetable tissues and insects; (8) Photomicrography; and an Appendix, containing a table of tumours.

The author's object has been (for the most part) not, as is so often the case, to describe a number of methods which have not been actually tried by the writer describing them, but to give a clear and short description of processes which he is in the habit of using himself, and which he has found to give uniformly satisfactory results.

Smith's 'How to See with the Microscope.'—This is a book of 410 pages and 33 figures (by Dr. J. Edwards Smith, a well-known American microscopist), a more extended notice of which must be deferred until later. In the meantime, we may mention that the leading idea which runs through the book is that of the superiority of wide-angled immersion-objectives, and it has been with peculiar interest that we have read Dr. Smith's remarks having regard to the recent revival of the old views of angular aperture. The author's remarks represent the state of our knowledge at a period which may be said to be half-way between the two extreme points—the period when no one supposed that wide-angled immersion-objectives could have any excess of aperture, in the proper sense of the term, over dry objectives, and that in which it was at last seen, not only that there *was* such an excess, but also how it acted.

Dr. Smith gives some very practical instances of the cases in which oil-immersion objectives exhibit a superiority of performance over all others, at the same time considering that the theoretical grounds for this superiority are beyond elucidation. As he puts it: "From a theoretical or mathematical standpoint, the study of balsam-"angles fairly bristles with difficulties; it has been to us a problem "to which our school-boy wrestlings with Euclid seem a pleasant "and simple exercise"—as indeed the question was to every one until Professor Abbe established not only the existence of the larger aperture, but also its specific function.

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* Seiler, C., 'Compendium of Microscopical Technology; a Guide to Physicians and Students in the Use of the Microscope, and in the Preparation of Histological and Pathological Specimens.' 130 pp., 1 pl., and 16 figs. (8vo, Philadelphia, 1881.)

PROCEEDINGS OF THE SOCIETY.

Meeting of 13th April, 1881, at King's College, Strand, W.C., The President (Professor P. Martin Duncan, F.R.S.) in the Chair.

The Minutes of the meeting of 9th March last were read and confirmed, and were signed by the President.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society were given to the donors.

	From
Duncan, P. M., and W. P. Sladen.—A Memoir of the Echinodermata of the Arctic Sea to the West of Greenland. 80 pp. and 6 plates. (4to. London, 1881)	*Prof. P. M. Duncan.*
Kölliker, A.—Entwicklungsgeschichte des Menschen und der Höheren Thiere. 2 vols. 1033 pp. and 606 figs. (8vo. Leipzig, 1876–9)	*Mr. Crisp.*
Smith, J. E.—How to See with the Microscope. 410 pp. and 33 figs. (8vo. Chicago, 1880)	*The Author.*
Four slides of kidney and spinal cord of cat (injected) and 3 photographs of the embryo of the chick, 24, 36, and 72 hours after commencement of incubation (from the Pathological Laboratory, Albany Medical College, U.S.A.) ..	*Dr. W. Hailes.*

Mr. T. Powell exhibited an oil-immersion $\frac{1}{8}$-inch objective of 1·47 num. aperture, the highest aperture that had hitherto been made.

Mr. Crisp exhibited a movable stage, intended to be clamped upon an ordinary stage (of German construction); also a "Butterfield broad-gauge screw" (see p. 301).

In accordance with the arrangement made at the last meeting, the subject of the Society Standard Screw was further discussed by Mr. J. Beck, Mr. Bevington, Mr. Crisp, Mr. Crouch, and Dr. Millar.

Mr. Beck insisted upon the necessity of having the steel plugs and rings to be used as gauges for determining the sizes of the top and bottom of the screw to be cut, and the master tap or "hob" for cutting screw tools, which were originally determined upon by the Committee, and contended that the taps and dies now issued by the Society, not being made on the plan originally designed by Whitworth, were not sufficient for the purpose of establishing a standard.

Mr. Bevington said that it must be borne in mind that it was not intended that the taps should be used as every-day working tools for cutting the threads, but that they should be kept as gauges from which proper templets could be prepared for ordinary use.

Mr. Crouch said that he had always used them as gauges, and not as working screw tools.

Mr. Crisp said that he could not pretend to discuss with Mr. Beck the practical question; all he could do was to point out that the gauge and screw tools which were now being issued by the Society were identical with those which the Sub-committee appointed in 1857 ultimately decided should be issued. This was shown by comparison with an original set belonging to Mr. Gay, which was produced to the Meeting.*

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* The reasons which induced the Committee to substitute a tap and pair screw tools for the cylindrical gauges and hob recommended in their first report of 12th November, 1857 (see Trans. Micr. Soc. Lond., vi. (1858) pp. 39–41) were thus stated by Mr. Charles Brooke, F.R.S., Past-President of the Society (see Trans. Micr. Soc. Lond., vii. (1859) pp. 92–7). The remarks are appended to a paper of the late Mr. Richard Beck:—

"It is unquestionable that an exact counterpart of the hob may be made by a screw-cutting lathe; but, for so fine a thread, screw-tools may probably be equally well hand-made by a practised workman. As very few opticians either possess traversing lathes, or have had much experience in making screw-tools, it was thought more desirable to have some screw-tools made from Whitworth's hob by an experienced workman, and supply them at cost price to the manufacturers.

"The practical difficulties that occurred in the use of the cylindrical gauges may be thus explained. It is manifest that if the inside and outside screws were exactly the same size, that is, had exactly the same longitudinal section, they would fit each other as tightly as the cylindrical gauges, and would therefore be useless for the purpose proposed. One of three courses must therefore be adopted —either

"1. The outside screw being made to the exact gauge size, the inside screw must be made a little larger,—or

"2. The inside screw being made to the exact size, the outside screw must be made a little smaller,—or

"3. Both inside and outside screws must be made to vary a little from the exact size.

"It soon occurred in practice, that object-glasses by one maker, who adopted the first course, would not enter the body of a Microscope by another maker, who adopted the second course; and thus the proposed universality of the screw was so far set at naught.

"As both the top and bottom of the outside screw can be most easily gauged, it appeared to the committee more desirable to adopt the first course, by giving a little ease to the inside screw; and in order to ensure uniformity, to have a number of steel taps or gauges made of such a size, that if the body of the Microscope were made to receive one of them tightly, an object-glass having an outside screw of the exact proposed dimensions would enter it easily and pleasantly. These taps must necessarily, for the reasons previously stated, be some two or three thousandths of an inch larger than the gauge size.

"It does not appear that the cutting points of the ingeniously contrived adjustable screw-cutting gauges proposed by the author of the paper possess any immunity from the same wear as that to which, as he justly remarks, the screw-tool is liable: nor would the mechanical effect of setting out the cutting points differ from that of taking a slightly deeper cut with the screw-tool.

"The form of the inside fitting represented in the drawing that accompanies the paper, namely, with a plain part beyond the screw, was that originally recommended; but as the committee were informed by the author of the paper, as well as by another leading firm, that it would be more convenient in practice to continue the inside screw to the full extent that the object-glass enters, and that it was their intention to do so, the committee thought that it would be better that their recommendation should in this respect be rendered conformable to the existing practice. It was also considered that this course would supersede the

Dr. Millar said that what the Society had hitherto supplied that they were supplying now.

Mr. Shrubsole read a paper on "The Diatoms of the London Clay" (see p. 381).

The President inquired if Mr. Shrubsole had found the sulphide of iron filling the interstices of the diatoms?

Mr. Shrubsole said he found it partly so in some instances and entirely so in others; it did not always replace the silica.

Mr. G. D. Brown thought that the species of *Triceratium* referred to were not the same as those now found in the Thames.

The President said that those who studied this class of subjects would be greatly interested in the paper which had been brought before them. The London clay had at the bottom of it considerable beds of pebbles, and they were all waterworn and were produced on an old shore. Above this pebble bed on a sinking shore would be just the place where they should expect to find diatoms. But the London clay further above became a little more marine. Then it should be remembered that the occurrence of diatoms was subject to great variations, and they were always found on the sea floor in greatest abundance in the neighbourhood of siliceous rocks or of their wreckage. As regarded their age, he thought there could be no doubt that they lived at the time of the lower Eocene. There were, however, some special peculiarities about the London clay, there being no other strata of the age which were known to have been deposited under the same conditions. It was not a reef deposit or deep-sea deposit, but it positively told the story of a sea, and an open estuary leading to a very large river. This was one reason why they would not find the

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influence of unavoidable minute differences in the gauge-taps, while it would not, in any degree, interfere with the fitting of the object-glasses.

"It may, in conclusion, be remarked, that the plan last recommended by the Microscopical Society has been found to work well amongst those who have adopted it, their object-glasses being interchangeable; and that several Microscopes, to which the standard screw has been applied by the author of the paper, have since been altered in other hands, so as to receive the proposed gauge-tap, and consequently the object-glasses of all the principal makers; and, further, that the slightly increased looseness of fitting of their own object-glasses has not been found to occasion any practical inconvenience."

See also the following appended to Proceedings of 16th June, 1858:—

"Some difficulties having occurred in the practical application of Whitworth's gauges recently recommended by the Society for the purpose of establishing an uniform screw for object-glasses, it was resolved at the meeting of the Society on May 19, that 'Two dozen steel taps be made for the use of makers of Microscopes, wishing to adopt the universal attachment for object-glasses recommended by the Society.'

"If one of these taps be made to enter the body of the Microscope it will receive any object-glass having a screw of the dimensions recommended, and the cylindrical gauges will not be required." (Quart. Journ. Micr. Sci., vi. (1858) p. 258.)

Also Resolution of 30th March, 1859:—

"It was resolved, That the microscope-makers who adopt the standard screw be requested to ascertain that one of the gauge-taps, recommended by the Society, will enter the bodies of their Microscopes to the extent of three-tenths of an inch." (Quart. Journ. Micr. Sci., vii. (1859) p. 263.)

diatoms in deposits of similar age in Italy. It was not an uncommon thing to find that other fossils made of carbonate of lime had it replaced by sulphide of iron. Phosphate of lime was often also replaced by sulphide of iron and the interstices of other fossils were often found filled with this same substance which was an exceedingly common mineral in the London clay. Silica was not the difficultly soluble substance which it was formerly thought to be, so that its place could be filled up by any other mineral which was less soluble than itself; and he thought the whole thing might be very fairly explained on the principle of pseudomorphism. But when they came to the question of antiquity, it was not so easy to give an opinion as to whether Count Castracane's diatoms named from the carboniferous series were really of that period. In the Tertiary deposits of course diatoms were found; but if Count Castracane's determinations held good, they ought to be found in the intermediate series of the Secondary age.

Mr. Shrubsole said Mr. Kitton's idea was that Count Castracane's fossils were fresh-water diatoms which had got washed down into the coal beds.

The President stated that there were fresh-water deposits where there were coal beds, and that he did not think much of the objection.

Mr. Crisp explained, by means of a black-board diagram, the action of the vertical illuminator when used with a transparent object adhering to the cover-glass.

Mr. Powell said he quite agreed that it was not opaque illumination.

Mr. Stewart exhibited and described the transverse section of an Indian wood having the native name of "Muhkta." It showed alternate layers of xylene and phlœm separated by layers of fundamental tissue, the structure being due to the periodic re-formation of cambium from the superficial fundamental tissue.

Dr. J. Anthony's paper "On Sliding Stage Diaphragms" was read by Mr. Crisp, diagrams in illustration being enlarged upon the black-board (see p. 520).

Mr. Beck inquired if it was proposed to put the piece of card under the object?

Mr. Crisp said that that was so; in recent years the tendency had been to bring the diaphragm nearly flush with the stage.

Mr. Ingpen was glad that the utility of small diaphragms placed closely below the object was being recognized in this country. On the Continent this method (known as the "Oberhauser system") was preferred to the wheel of apertures at a fixed distance. A diaphragm, having an aperture of about the diameter of the field of view, was placed close underneath the object, or removed a small distance from it according to the quantity of light required. This was exactly the same as "Varley's dark chamber," devised by

Cornelius Varley more than forty years ago, but now seldom met with, though there were few methods of illumination more effective.

Mr. Crisp referred to a communication from E. Hallier as to the cause of the movements of diatoms (see p. 509), in which the author did not agree with the view expressed by C. Mereschkowsky, founded on the phenomena of endosmose and exosmose (see p. 102).

The President said if they wanted to see diatoms to the best advantage they must try and see them under their natural circumstances. If they were put upon a slide with a glass cover over them, the water became chilled, and their movements were to a great extent stopped; but if the slide was slightly warmed their activity was increased to a much greater degree than usual. Under proper conditions, with a $\frac{1}{16}$-inch objective, he had distinctly seen the wavy movement of the protoplasm on the outside; but the impression was strong upon his mind that there was something else concerned in the movement in addition to this. It struck him that a good deal of the movement was produced by the action of heat currents in the water, for the things were so light as to be most easily influenced in that way.

The President reminded the Fellows that the second Conversazione of the session would take place on the 20th inst.

The following Objects, Apparatus, &c., were exhibited:—

Mr. Beck:—"Economic" Microscope with swinging substage.

Mr. Crisp:—(1) Butterfield Broad-gauge Screw. (2) German Movable Stage.

Mr. Powell:—$\frac{1}{8}$ Oil-immersion Objective of 1·47 Num. Ap.

Mr. Stewart:—Section of Indian Wood ("Muhkta").

New Fellows.—The following were elected *Ordinary* Fellows:—Messrs. W. P. Collins, C. Thomas, F.G.S., W. Thompson, and T. P. Watson.

CONVERSAZIONE.

The Second Conversazione of the Session was held on the 20th April in the Libraries of King's College, when the following objects, &c., were exhibited:—

Mr. C. Baker:
  Model Histological Microscope and Histological ditto by Carl Zeiss.
Mr. E. J. Creese:
  Bread from the Ruins of Pompeii.
Mr. T. Curties:
  Indian Parasites.

Mr. L. Dreyfus:

Preparation of *Synapta* mounted by the Zoological Station, Naples.

Professor M. Duncan:

1. An acuate, entirely verticillately spined, spicule with enlargements in the central canal: deep sea, Japan.
2. Acuate bent at one end, enlargements in axial canal and radial penetrations from without.

Mr. F. Enock:

Tongue of saw-fly, *Trichiosoma lucorum*, and of honey-bee, *Apis mellifica*, showing the muscular structure.

Mr. W. H. Gilburt:

Section of ovary of tulip, showing the division of primary nucleus in the embryo-sac.

Mr. J. W. Groves:

1. Testis, epididymis, and vas deferens of guinea-pig (in one section), stained with logwood and anilin green.
2. Vertical section of cat's lip with tactile hairs, double stained.
3. Spinal cord of monkey, stained with logwood, anilin black, and eosin.

Mr. J. Hood:

Cristatella mucedo.

Mr. John Hunter:

Longitudinal sections of the jaws of mole.

Trichina spiralis from man.

Dr. Matthews:

Images produced by diatoms and small perforations in tinfoil.

Mr. Wm. Moginie:

Live *Poduræ.*

Mr. A. D. Michael:

Living specimens of *Leiosoma palmicincta* (inert stage before ecdysis) and *Dermaleichus heteropus* n. sp.

Mr. Edward M. Nelson:

Surirella gemma with Powell and Lealand's oil-immersion $\frac{1}{12}$ by direct light and achromatic condenser.

Messrs. Powell and Lealand:

Amphipleura pellucida with oil-immersion $\frac{1}{8}$ having a numerical aperture of 1·47 in crown glass = (angle 150°) and vertical illuminator.

Mr. B. W. Priest:

Palate of *Pleurobranchus membranaceus.*

Mr. G. J. Smith:

Sections of dolerite with unaltered olivene and syenite, from Peru.

Mr. James Smith:

Pleurosigma quadratum, $\frac{1}{16}$ immersion objective.

Section of whalebone with monochromatic light.

Mr. Sigsworth:

Platino-cyanide of yttrium of various forms.

Mr. Charles Stewart:

Acineta living in sponge, *Halichondria panicea.*

Mr. A. Topping:
- Voluntary muscle of pig showing ultimate fibre. *Trichina spiralis* in human muscle.

Mr. J. G. Waller:
- Iridescent glass (part of a Roman lacrymatory).

Mr. F. H. Ward:
- Ova, larva, and male and female of *Bopyrus squillarum.*

Mr. W. Watson:
- New Patent Microscope-stand.

Mr. B. B. Woodward:
- Section of *Eozoön canadense,* showing canal structure.

Mr. E. Wheeler:
- *Trichina spiralis,* encysted, from man and pig. The sexes separated from the intestinal canal.
- Larva of bot-fly from stomach of a horse.
- Fluke from liver of sheep.
- *Sclerostoma syngamus* from chicken ("gapes").
- Sections of pollen-grains, ovaries, and illustrations of the reproductive organs in plants.

MEETING OF 11TH MAY, 1881, AT KING'S COLLEGE, STRAND, W.C., THE PRESIDENT (PROFESSOR P. MARTIN DUNCAN, F.R.S.) IN THE CHAIR.

The Minutes of the Meeting of 13th April last were read and confirmed, and were signed by the President.

The List of Donations (exclusive of exchanges and reprints) received since the last meeting was submitted, and the thanks of the Society given to the Donors.

	From
Seiler, C.—Compendium of Microscopical Technology. 130 pp., 1 pl., and 16 figs. (8vo, Philadelphia, 1881) ..	*Mr. Crisp.*
2 slides of *Hydrosera tricoronata* n. sp.	*Dr. H. Stolterfoth.*

Mr. Crisp exhibited Houston's Botanical Microscope (see p. 514), Nachet's Binocular Dissecting Microscope, Vérick's Skin Microscope (see p. 516), a selection of slides from the Naples Zoological Station, and Cohen and Grimm's Microphotographs of Minerals and Rocks.

The President, in reply to a question as to the scientific value of photomicrographs of rock sections, said he had had some experience in the matter, and was of opinion that uncoloured sections of rocks photographed in that way were of considerable use. The art had now been carried on for some time with more or less success, and he had seen some sections—particularly those of eruptive rocks—which were very wonderful, and which gave a most excellent idea of the structure of the different crystals contained in them.

Mr. Curties described a polarizing Microscope by Seibert, which he exhibited.

Mr. Sigsworth requested permission to ask a question with regard to a paragraph in the last Report of the Council.

The President thought that as the meetings were intended chiefly for the consideration of matters of scientific interest, it would be better if questions on business were referred in the first instance to the Council, as it was often impossible to deal properly with questions of which no previous notice had been given.

Mr. Sigsworth said he desired to refer to the second paragraph of that portion of the Report relating to the "Proceedings at the Meetings" (see *ante*, p. 370), and to inquire if the papers which were summarized at the meetings were also similarly summarized in the Journal?

Mr. Crisp said they were not, but that all the communications which were accepted by the Council as papers, and so read at the meetings, were printed *in extenso* in the Transactions. Notes were printed in the Summary.

Dr. E. Cutter's letter was read affirming the correctness of his observations on *Asthmatos ciliaris* as the cause of one form of epidemic influenza (see *ante*, p. 376).

Mr. Stewart described what he believed to be a new and very interesting annelid, which had been brought up on the Eastern Telegraph Company's cable raised for repairs in the neighbourhood of Singapore.

Mr. Groves asked if Mr. Stewart had any idea as to the way in which the calcareous plates attached to the jaws of these worms acted in cutting or boring?

Mr. Stewart said he had not been able to detect any special structure in connection with them which would enable him to say with certainty, but his impression was that the boring might be done by some sort of rotating action, like that of a cheese-taster.

The President said that some time ago the Telegraph Maintenance Company took up a cable off the north coast of Spain, which had been down about six years, and they sent him a piece in order that he might be able to form an opinion as to the rate at which deposits were formed at the bottom of the sea. The cable was laid in the first instance on soft oozy ground—globigerina ooze—and had no doubt partially sunk into it, though they had no means of ascertaining how far. He found that corals and polyzoa had begun to grow on it, and a number of minute corals were brought up alive; some of these were about $\frac{1}{4}$ inch long; most of them were upon the top of the cable, but some had grown a little way down the side, and he was enabled to judge from these appearances that scarcely any deposit had accumulated during the period the cable had been down. But he noticed as a very curious fact, that nearly all the corals were more or less deformed, and one kind which was found on the top—evidently a species of *Lophohelia*—was not like any other that he had ever seen. Worms appeared to be numerous, and nearly every one was found to be partly surrounded by coral. There were many simple corals, and he noticed that their bases were much interfered with by the worms getting out of the cable, and they seemed on that account to have put out a number of small buttresses extending down to the cable. He could never trace any portions of the worms which had done this; the cable had, however, been penetrated in various places by them. With regard to the very curious jaws described by Mr. Stewart, there were found in the fossil state in the palæozoic rocks objects which were called "Annelid Jaws"; they had been carbonate of lime originally, but he thought they bore no relation either in position or structure to those which Mr. Stewart had described—they were rather of the nature of grinding jaws.

Dr. Matthews said that at the last Scientific Evening of the Society he had exhibited some images of well-known forms (S and +) produced in two ways. First, by the areolations of various diatoms (such as *Triceratium*, *Coscinodiscus*, &c.). The second, by very minute holes in thin laminæ (such as tinfoil, &c.).

In the first of these cases he had noticed that a very definite and perfect focal image was formed, which was lost by focussing above, and below, the focal plane. In the second case, although a very perfect image was formed, yet no distinct focus was produced, the image merely increasing or diminishing in proportion to the distance or power of the objective by which the image was examined. The inference he drew was, that nearly all diatoms were lenticular in their areolations, since he had never discovered, by any power at his command, in any diatom such a condition of image as at all resembled that produced by the second of the methods employed. He was well aware that this had been disputed, and he, therefore, did not definitely assert that *all* diatoms were lenticular, but he certainly thought that a strong case had been made out, by his experiment, in favour of that view.

Mr. Crisp said that both Mr. J. Deby and Count Castracane had controverted the views of M. Prinz as to the existence of openings, and he explained in detail the grounds on which their objections were based (see p. 508).

Mr. James Smith said he was some time ago examining a slide of *Pleurosigma formosum*, and found the markings all distinctly separated from each other, like chessmen on a board, looking like a plane with a number of plano-convex lenses laid upon it.

Mr. Beck said that whether the markings on *P. angulatum* were elevations or depressions, it was quite certain that the effect described could be produced by elevations. When minute globules of silica were deposited from a solution, they formed a most perfect artificial *angulatum*, and if they were obtained a little larger the hemispherical globules of silex could be seen with the greatest possible plainness.

He thought, therefore, that the opinion expressed received confirmation from the effect produced by an object which they knew for certain consisted of globules of silex.

Dr. Stolterfoth's paper "On a New Species of *Hydrosera* (Wallich)" was read by Mr. Stewart (see p. 424).

Professor Abbe's notes on some points connected with stereoscopic vision were read and explained by Mr. Crisp.

Some discussion ensued, more particularly as to the proper use of the term "stereoscopic vision," in which Mr. Beck, Mr. Crisp, Mr. Curties, the President, and Mr. Ingpen took part.

Mr. James Smith exhibited and described two pieces of apparatus which he had shown at the last Scientific Evening of the Society.

The following Instruments, Objects, &c., were exhibited:—

Mr. Crisp—(1) Houston's Botanical Microscope (see p. 514). (2) Nachet's Binocular Dissecting Microscope. (3) Vérick's Skin Microscope (see p. 516). (4) Slides from the Naples Zoological Station.

Mr. Curties—Seibert's Polarizing Microscope.

Mr. J. Smith—The Apparatus referred to above.

Dr. H. Stolterfoth—*Hydrosera tricoronata* n. sp.

New Fellows.—The following were elected *Ordinary* Fellows:—Messrs. C. F. Cox, R. J. Parker, G. S. V. Wills, and B. W. Wood.

On the Estimation of Aperture in the Microscope.

By Professor E. Abbe, Hon. F.R.M.S.[†]

(*Read 9th March*, 1881.)

In originating the "*numerical*" definition of aperture, my special aim was to signalize the all-important fact, so long overlooked and even denied, of the existence of an *unequal equivalent of equal aperture-angles in different media*; to propound a simple and exact expression by means of which this unequal equivalent could be estimated; and thus to afford a definition of aperture for the practical comparison of objectives, which should exhibit the true relation of aperture to the *actual performance* of the Microscope, a relation which is entirely concealed by the *angular* expression.

As some little time must probably still elapse before my more extensive paper "On the Function of Aperture in Microscopical Vision" can be completely printed (a great part of which was laid before the Meeting of the Society in June 1880 [‡]), it has been suggested to me that it may be useful if I here summarize the principal considerations which bear upon the determination of the aperture-equivalent in the Microscope.

I.—*Definition of Aperture by the Ratio of "Opening" and Power.*

The general notion of "aperture," which every one forms *prior* to attempting any distinct definition of the term, unquestionably refers to the greater or less number of rays which are collected and utilized by an optical instrument—consequently, to the *opening* of the lenses or lens-systems, and to that alone. Every definition of the term must conform to this primary idea.

In the case of a telescope-objective the *absolute* opening of the lens is itself the proper expression of aperture; because in the depiction of *distant* objects by parallel (or approximately parallel) rays, no other element can have any influence on the larger or smaller number of rays admitted from an object at a definite distance. This is a matter of general agreement.

If we consider the case of the Microscope, however, the matter is not quite so simple.

(1) In a *single*-lens Microscope it is evident that the number of rays admitted within one meridional *plane* of the lens increases in the proportion of its clear diameter, provided all other circumstances are the same. For if the lens projects a distinct image to a

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[†] The original paper is written by Prof. Abbe in English.—Ed.

[‡] See this Journal, iii. (1880) p. 735.

distance which is great in comparison with its diameter—as is always the case in the Microscope—we have *at the back* of the lens the same circumstances as are *in front* when a telescope-objective is considered. Consequently, the larger or smaller number of *emergent* rays will be properly measured by the clear diameter; and as no rays can emerge which have not been taken in, this estimation must apply at the same time to the *admitted* rays,—other circumstances, in particular the distance of the radiant from the lens, being equal.

The question, however, will now arise, how is the difference of these *other* circumstances on the microscope-lens to be taken into account?

A simple consideration shows at once that this is properly done by taking the *absolute* diameter of the lens (or its "opening") *in proportion to the focal length.* When two lenses have equal openings but different focal lengths, they transmit the same number of rays to equal areas of an image at a definite distance, because they would *admit* the same number if an object were substituted for the image, that is if the lens were used as a telescope-objective. But as the focal lengths are different, the amplification of the images is different also, and equal areas of these images correspond to different areas of the object, *from* which the rays are collected. Therefore the higher-power lens with the same opening as the lower power, will admit a *greater* number of rays in all from one and the same object, because it admits the *same* number as the latter from a *smaller* portion of the object. Thus if the focal lengths of two lenses are as 2 : 1, and one of them amplifies an object N diameters, the other of shorter focal length will amplify the object 2 N diameters with the same distance of the image. Consequently the rays, which in both cases are collected *to* a given field, say of 1 mm. diameter, of the image, are admitted *from* a field of $\frac{1}{N}$ mm. in the first case, and of $\frac{1}{2N}$ mm. in the second. If now the idea of aperture referred to the photometrical *quantity of light*, the capacities of equal openings with different focal lengths would of course be in the inverse ratio of the *areas* from which equal quantities are admitted, and would then be in the direct ratio of the *squares* of amplification. Inasmuch, however, as the *opening* is estimated by the diameter and not by the area, the consideration is confined to the rays which travel within one meridional *plane* of the lens, and the same principle must be applied to the *fields* from which the rays are admitted; which must also be estimated by their *diameters*. The higher-power lens in the example given above therefore admits *twice* as many rays as the lower power, because it admits the *same* number from a field of *half the diameter*; and, in general, the admission of rays with different focal lengths (the opening being the same) must be in the inverse ratio of the focal lengths.

In a single-lens Microscope, aperture must be determined, therefore, by the *ratio between the clear opening and the focal length of the lens,* in order to define the *same* thing, as is denoted in the telescope by the *absolute opening.*

(2) Regarding now *composite* systems—the most important case in the Microscope—the further question arises, what is the opening of *such* a system? The actual opening, which limits physically the transmission of the light through a composite objective, varies according to particular circumstances. It may be the margin of the front lens, or of any one of the posterior lenses, or it may be a diaphragm inserted in some part of the system. As the cone of admitted rays expands continuously from the radiant up to the back lens, the same objective admits of innumerable different openings of this kind, which nevertheless may indicate the same aperture, and thus no definite opening could be assigned. This ambiguity cannot be removed unless we adhere to the diameter of the admitted cone at that plane where it has its *ultimate maximal* value, which is obviously the diameter of the pencil at its emergence from the system, or, practically, the *clear effective diameter of the back lens.* The emergent pencil from a microscope-objective, converging to a relatively distant focus, has its rays approximately parallel, and the conditions are once more similar to those of the telescope-objective on the side of the object. The diameter of this emergent pencil, whether it emerges from a single lens or from a composite system, must therefore always have the same signification.

The influence of the power or focal length also remains the same as in the case of the single lens. An objective with a focal length equal to half that of another admits with the same linear opening twice as many rays as the latter, because the amplification of the image at one and the same distance is doubled, and the same number of rays, consequently, are admitted by the higher power from a field of half the diameter. *This must hold good, whether the medium at the object is the same in the case of both objectives, or different.* For an immersion system and a dry system always give the *same* amplification when the focal length is the same.

Thus we have as general propositions for all kinds of objectives: (*a*) the admission of the rays with one and the same power or focal length varies with the linear diameter of the pencil at its emergence; (*b*) with different powers, the *same* admission requires different linear openings in the proportion of the focal lengths—or conversely, the admission by one and the same opening is in *inverse* proportion to the focal length. *Consequently the aperture of an objective is always exhibited by the ratio between the linear* *opening (at the plane of emergence) and the focal length of the system.*

There is no other rational way of defining the admission of rays to an objective, and consequently no other definition of aperture which agrees with this fundamental idea. I need hardly say that this suggestion is nothing *new*. It is a matter of general consciousness; for every one will agree that the aperture of a given objective is altered when the utilized diameter of the back lens is changed by the application of different stops; and that a clear opening of say 3 mm. in a $\frac{1}{4}$, is *less aperture* than the same clear opening in an $\frac{1}{8}$.

On the other hand, it is true that the apertures of objectives may be compared *as regards equality or inequality merely* by the angles of the admitted pencils, if the medium at the radiant is the same, because *under this condition* equal angles indicate an equal admission of rays, and different angles different admission. The assumption, however, that *apertures* can be defined or compared by the angle *alone*, is an entirely arbitrary one unless it were proved that the admission of rays is always in proportion to the angle, and does not depend on any other element. As no attempt at a proof has been brought forward in support of this hypothesis (it being in reality, as will be seen hereafter, opposed to the fact), the proper way of obtaining a correct expression of aperture *by means of the angle* will be to investigate *what* expression must be taken, in order to define the same thing as is denoted by the ratio of opening and focal length.

Until a comparatively recent period the above assumption has persisted as a dogma—without any investigation of the subject. The author may claim to have been the first to put this dogma to the test of scientific principles and to point out its fallacy by the indication of the *unequal* aperture-equivalent of objectives.

The demonstration of the *general* validity of this fact is given here in detail for the benefit of those who may care for such a treatment of the question.

II.—*Determination of the relative Openings of Systems by the Aperture-angle and the Refractive Index of the Medium.*

In 1873 the author and—quite independently—Professor Helmholtz established a general relation between the pencil of rays *admitted* by an optical system and the pencil *emerging* from it; a relation which pertains to the angles of convergence in both pencils, and must always obtain whenever a system is *aplanatic*, or is capable of depicting an object by means of wide-angled pencils. The proposition is:—

Let O and O* (Fig. 1) be the conjugate aplanatic foci of a wide-angled system; u, U the angles of inclination of *any two* rays admitted from the radiant, and u^*, U* the angles of the same rays on their emergence; then we shall have always

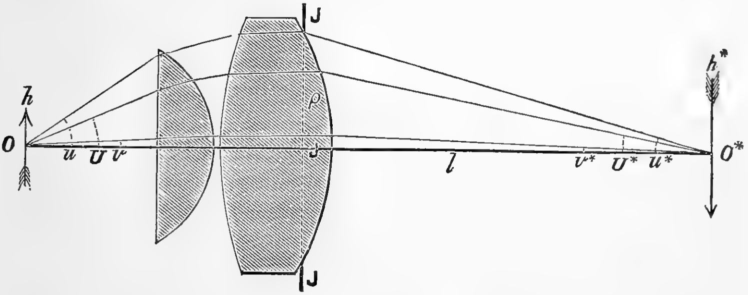
$$\sin U^* : \sin u^* :: \sin U : \sin u;$$

or

$$\frac{\sin U^*}{\sin U} = \frac{\sin u^*}{\sin u} = \text{const} = c; \qquad (1)$$

i. e. the *sines* of the angles of conjugate rays on both sides of an aplanatic system always yield one and the same quotient c, whatever rays may be considered, as long as the same system and the same foci are in question.

FIG. 1.



This proposition holds good for every composition of the system (every arrangement of media and refracting surfaces), and for every position of object and image. In point of fact, the *law of convergence for aplanatic systems*, as indicated above, is the *necessary* condition (physically and geometrically) on which depends the delineation of an image by means of wide-angled pencils. When in any case the convergence of the rays in a system of lenses is not in accordance with this condition (very approximately at least) that system will be unfit for depicting an image of an object, except by *narrow*-angled pencils.

Microscope-objectives *do* of course depict images with wide-angled pencils, and consequently the proposition must apply to them without any restriction; the author, it will be remembered, has suggested a simple experiment † by which every one may satisfy himself that all such objectives, if moderately well made, are in perfect accordance with this statement.

Suppose now, that for any particular objective and any particular position of the conjugate foci of object and image, the value of the constant quotient c of formula (1) is determined numerically, in any way whatever; it will then be possible to compute the

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† See this Journal, iii. (1880) p. 511.

obliquity u^* of *any* emergent ray from the obliquity u of the same ray at its entrance, by means of the equation

$$\sin u^* = c \sin u\,; \qquad (2)$$

and if this equation is applied to the ray of *utmost* obliquity which is transmitted through the system, u^* will express the semi-angle of the emergent pencil, whilst u is the semi-angle of the admitted cone of light or the *semi-angle of aperture.*

The *linear* opening of the system, or the diameter of the delineating pencil at the plane of its emergence, is readily calculated by means of the angle u^* and the distance at which the image is projected. If J is the plane of emergence (the plane of the back surface of the system) and l the distance of the image from J, the linear *semi*-diameter ρ of the pencil is, obviously,

$$\rho = l \tan u^*,$$

for which may be substituted the identical equation

$$\rho = l \frac{\sin u^*}{\cos u^*}.$$

In the case of microscope-objectives, the distance l (the length of the microscope-tube) is always many times greater than ρ, and accordingly the angle of convergence u^* is always very small, never exceeding a few degrees. The *cosine* of such an angle may be put = 1 without appreciable error; and taking now the value of *sin* u^* from the equation (2) we obtain

$$\rho = c\, l \sin u, \qquad (3)$$

which expresses the linear semi-aperture of the system by the semi-angle of aperture.

The question will now arise: how is the value of c for every particular case to be obtained?

This is established by a dioptrical proposition of older date, which is known as the Lagrange-Helmholtz law of convergence of *infinitesimally narrow* pencils. If O and O* denote conjugate foci, h the diameter of an object at O, and h^* the diameter of its image at O*, n and n^* the refractive indices of the media in front and at the back of the system, whilst v and v^* are the angles of obliquity of any ray traversing the system *close to the axis,* then we have always

$$\frac{v^*}{v} = \frac{n}{n^*} \cdot \frac{h}{h^*}; \text{ or } = \frac{n}{n^*} \cdot \frac{1}{\mathrm{N}}, \qquad (4)$$

where N denotes the linear amplification of the system for that pair of conjugate foci; and this holds good for every composition of the system and for every position of the conjugate foci. According to this proposition, the ratio of infinitesimal angles v and v^* (pertaining to one and the same ray at its entrance and emergence) may be completely determined by the refractive indices of the media at the radiant and at the image and by the linear amplification of the image, *without regard to the elements of the optical system or to the position of the foci.*

This important theorem was established by Professor Helmholtz in 1866.[†] Its earliest origin must be traced back to Lagrange, who pointed out a similar proposition, confined however to less general conditions, in 1803.[‡]

The way in which equation (4) leads to a general determination of the constant c, which appears in the law of convergence of *wide*-angled pencils, will be readily understood. Any wide-angled cone of rays admitted to an aplanatic system, embraces axial rays of infinitesimal obliquities v and v^*, and as in the case of very small angles the ratio of the *sines* becomes identical with the ratio of the angles, the value of c in equation (1) must, as far as it pertains to those axial rays, coincide with the value of $\frac{v^*}{v}$ as determined by the Lagrange-Helmholtz formula. But as the condition of aplanatism requires the *same* value of the quotient $\frac{\sin u^*}{\sin u}$ for *all* rays of the wide-angled pencil, we must have for all cases

$$c = \frac{n}{n^*} \cdot \frac{1}{\mathrm{N}} . \qquad (5)$$

Introducing this expression of c into equation (3) and taking into account that in the case of the Microscope the medium at the back of the system is always air ($n^* = 1$), the linear semi-opening of an objective is

$$\rho = \frac{l}{\mathrm{N}} . n \sin u ; \text{ or } \rho = \frac{l}{\mathrm{N}} . a, \qquad (6)$$

a being put for n sin u, and therefore denoting *the product of the sine of the semi-angle of aperture and the refractive index of the medium* to which this angle belongs.

When an objective has a focal length $= f$ and an image is projected at a distance $= l$ from the lens, the amplification N of this image will be, very approximately,

$$\mathrm{N} = \frac{l}{f},$$

whence it follows

$$\frac{l}{\mathrm{N}} = f.$$

[†] 'Physiologische Optik,' 1866, p. 50.

[‡] Mém. Acad. Berlin, 1803.

The quotient appearing in the expression of ρ is thus shown to be nothing else but the equivalent focal length of the system; and we have now

$$\rho = f(n \sin u), \text{ or } \frac{\rho}{f} = n \sin u = a.\dagger \qquad (7)$$

The ratio of the linear semi-opening of any system to the focal length of the system is expressed by the value of a or by the "numerical aperture." The value of n sin u is the aperture-equivalent of every objective whatever may be the medium in which the radiant is placed.

III.—*Inferences from the Aperture-equivalent.*

The simple result of the foregoing demonstration may be summarized as follows:—

(1) There exists a definite ratio between the linear opening and the focal length of a system, which must be entirely independent of the composition and arrangement of the system, and *solely* determined by the above-mentioned aperture-equivalent of the admitted cone of rays. When this equivalent is the same, we have always the same proportion of opening to focal length, whatever may be the particular arrangement of refracting media in the system.

(2) A purely *angular* determination of aperture is shown to be irreconcilable with any rational notion of a term which must be defined essentially in relation to opening. Aperture it is seen cannot be expressed by an angle, nor by any mathematical function of an angle alone, but must be determined by a *composite function* of the angle and the refractive index of the medium to which the angle belongs.

(3) Even with one and the same medium at the radiant, aperture does not increase or decrease in proportion to the angle, but with the *sine* of the semi-angle (or the chord of the whole angle). If the angle is changed from 60° to 180°, the aperture is not changed in the proportion of 1 : 3, but of 1 : 2 only.

† The above formulæ hold good in *perfect strictness*, if the distance l of the image is taken *not* from the accidental plane of the back-surface, but rather from the posterior *principal focus* of the system (i. e. the place where are depicted distant objects in front of the system). The equation (7) will therefore afford a *strict* expression for the semi-diameter of the emergent pencil *at the plane of the posterior principal focus of the system.* In microscope-objectives of the ordinary type of construction that focus is always very near to the back lens of the system, and the difference may be disregarded practically.

At first sight it might appear to be more convenient to define the aperture-equivalent by $2\, n \sin u = 2\, a$, instead of a, in order to express the ratio of the *diameter* of the opening (instead of the *semi*-diameter) to the focal length. In mathematical dioptrics, however, the angles of the rays *with the axis*, and, correspondingly, the distances of points *from the axis* are always given as the effective elements. To introduce the double of these angles and distances is not only unnecessary, but would give rise to a somewhat inconvenient complication of all mathematical expressions.

(4) Equal angles of the admitted pencils from radiants in different media do not yield equal apertures, but apertures which are in the exact ratio of the refractive indices of those media. Thus the diameter of the emergent pencil of an immersion glass which takes in a cone of say 120° from an object in balsam, is *greater* in the proportion of 3 : 2 than the diameter of the emergent pencil of a dry lens of equal power admitting the same angle from an object in air. Attentive microscopists and opticians have long since noticed the fact, that immersion objectives require and utilize much larger back lenses than equal-power dry systems of similar aperture-*angle.*

(5) An immersion objective may have a greater *aperture* than any dry lens of even 180° aperture-*angle* can have. The maximal opening of a *dry* lens (i. e. the maximal diameter of the pencil emergent from such a lens) is shown by proposition (7) to be exactly double its focal length, for as $\rho = f\,(n \sin u)$ and $n = 1$ and $\sin u = 1$ for air, $\rho = f$ or (for the whole diameter) $2\,\rho = 2f$. No lens performing on objects in air $(n = 1)$ can therefore ever admit of a wider aperture, because no angle u is possible whose *sine* is >1. When, however, the object is in a denser medium (and no film of air with plane surfaces is between that medium and the system) an *angle* of aperture which is much less than 180° (exceeding only the double of the critical angle for the medium) will utilize and require a wider opening of the system than $2f$. The excess of the numerical aperture of an immersion glass beyond the unit gives a direct expression of the *surplus* of aperture over the maximal aperture of a dry lens of an air-angle of 180°.

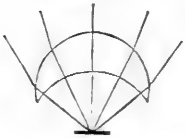
(6) The unit of aperture is exhibited by an objective which gathers-in the whole hemisphere of radiant light *in air.* The value of a for any given objective shows the capacity of that objective in comparison with the capacity of another of maximal air-angle.

Any one who has not comprehended the generality of the demonstration, may object that the greater or less opening required for the transmission of a pencil of given angle depends on the particular mode in which that pencil is refracted by the lens-surfaces of the system. A pencil of 120° in air requires, it will be said, a smaller opening than the same pencil in balsam when a homogeneous-immersion objective is used, because in a dry lens it is contracted on its entrance into the system by the refraction of the plane front-surface, whilst the pencil in balsam, owing to the abolition of the front-refraction by the immersion, is not subjected to such contraction, and *therefore* maintains a greater linear diameter up to the plane of emergence.

The fallacy of such an objection is readily shown: Take a front lens with a *concave* surface of admission, of such a curvature

(Fig. 2), that the focus or radiant for an uncovered object is exactly at its centre. The refraction is now abolished (in regard to the pencil from the radiant) just as if there were homogeneous immersion. If the above-mentioned view were correct, the consequence ought to be, that a dry lens with such a front would utilize a wider opening than an equal-power dry lens of the ordinary plan, and the same opening as an equal-power immersion glass of a balsam-angle equal to the air-angle in question. But, of course, the contrary is the actual fact. An ordinary dioptrical computation shows that whenever such a dry objective with concave front has the same power or focal length as a plane-front system of equal aperture-angle, its opening must be also the same, exactly —as the general principle of formula (7) indicates.

Fig. 2.



A misapprehension on this point has arisen thus:—If a homogeneous-immersion objective is taken, and its front-surface is ground to a concave of the above description, *whilst all other elements are left unaltered,* the angle admitted from air by the objective will be no wider than that which was previously admitted from balsam, but nevertheless the full opening will still be utilized. This seems to prove, and indeed has been asserted *to* prove, that after abolishing the front-refraction, a given air-angle will yield the *same* opening as an equal balsam-angle. This, however, is a transparent fallacy. According to well-known elementary propositions, a concave surface *diminishes* an object at its centre in the proportion of the refractive index n of the lens-substance. Consequently, the objective in question has been changed into an n-times *lower* powei ; and utilizing still only the *same* (and not a larger) back lens, it has necessarily a *smaller* aperture. To restore the original focal length it would be necessary to increase the depth of the posterior lens-surfaces in such a way that the pencil should be by them contracted to the same small diameter which otherwise it would have had with a plane front.

Whatever particular composition of objective is considered, the result must always be the same. The relation between the aperture-angles for different media and the corresponding openings of the systems, as defined by proposition (7) cannot depend in any way on the manner in which the pencils are refracted in the system. A pencil from a radiant in air must *always* yield a smaller aperture than an *equal* pencil from a radiant in balsam, whether there is refraction or no refraction at the front surface of the system. *Consequently the difference of aperture with equal angular pencils in different media must originate from a difference in the pencils themselves, that is, must be founded on the different physical nature of pencils in different media.*

IV.—*Experimental Demonstration of the Aperture-equivalent.*

In the foregoing discussion I have demonstrated the aperture-equivalent without regard to experiment and on *general* optical principles only, as is necessary for an exhaustive scientific settlement of the subject. A theoretical discussion of this kind is, however, by no means required for demonstrating the *essential* principle of "numerical" aperture. That there is an *unequal equivalent of equal angles in different media* in regard to *aperture*, is a fact which may be readily shown by observations of the most simple character. I confine myself to a few examples which have been referred to in previous discussions.

(1) If any dry lens of an aperture-angle w for objects in air, is focussed on a balsam-mounted object, with a *plane* surface of exit, the aperture-*angle* at the radiant is of course reduced to a smaller angle v, according to the condition

$$n \sin \frac{v}{2} = \sin \frac{w}{2},$$

in which n denotes the refractive index of the balsam. It is, however, clear *that the amplification of the image is not changed*—the power of the system is the same still—whilst the linear diameter of the emergent pencil remains the same also. Consequently, the ratio of the opening to the focal length—i. e. the aperture—is not reduced.

This simple fact thus contains a direct proof of the proposition that *different angles* in different media may denote *equal apertures.*

The idea of aperture being, has as been said, dependent on that of "opening," the assertion that aperture is "cut down" by the balsam, or by the immersion, is obviously an abuse of the term, independently of the fact that the assertion is not supported in any way by what we know as to the actual performance of objectives with these "cut-down" apertures.

(2) Moreover, suppose the same objective of $w°$ air-angle to be focussed on an object in balsam, the surface of exit, however, being no longer a plane surface, but a spherical one, the object being at the exact centre of a small hemisphere of glass or balsam;—or suppose the original objective to be provided with an extra immersion-front, the centre of the curvature of which coincides with the focus. In this case the *angle* of the admitted pencil will be the same for the radiant in glass or balsam as it was for the radiant in air; and the clear opening will also be the same still. It would, however, be obviously a mistake to say that the objective had now undergone *no* change of aperture, or that the *full* aperture was *now* made to bear upon a balsam-mounted object. For it is an

elementary truth that a hemisphere of refractive index *n amplifies* an object at its centre by exactly *n* diameters. Consequently the hemisphere or extra front has changed the original objective into one of *n*-times higher power or shorter focal length, *but it nevertheless utilizes the full opening of the lower power.* Consequently the aperture is also increased in the proportion of 1 : *n*, whilst the aperture-*angle* remains the same.

If, for instance, a $\frac{1}{4}$ of, say, 60° air-angle has the extra front of crown glass, it would be converted into a $\frac{1}{6}$ of 60° *balsam*-angle, utilizing *the full original opening* of the $\frac{1}{4}$. But a $\frac{1}{6}$ of 60° *air*-angle would of course have a smaller opening than a $\frac{1}{4}$; for such an objective would be obtained by reducing all elements of the former $\frac{1}{4}$ in the proportion of 3 : 2, whereby the opening for the air-angle of 60° would be reduced in the same proportion.

Thus it is shown that *equal angles* pertaining to different media are *different apertures.*

(3) The other inference from the principle of the aperture-equivalent—that an immersion objective can have a *greater* aperture than the widest-angled dry lens—also admits of a direct experimental demonstration. Mr. Stephenson † has already pointed out the remarkable experiment (and has given due prominence to its bearing on the aperture problem), by which it is shown to every one's *eyes* that the aperture of a wide-angled immersion glass is *cut down*, when it is made to act as a dry lens even with an angle of nearly 180°. Take any immersion objective of balsam-angle exceeding the double of the critical angle, and focus it on a balsam-mounted object which is illuminated by any kind of immersion condenser, in such a way, that the whole range of the aperture-angle is filled by the incident rays. Remove the eye-piece and place the pupil of the eye at the place where the air image is projected by the objective, and look down on the lens. You see a uniformly bright circle of well-defined diameter which is the true cross-section of the image-forming pencil emerging from the Microscope (for the eye receives now all rays which have been transmitted through a small central portion of the object—that portion which is conjugate to the pupil—and receives *no other* rays). After this, focus the *same* objective on an ordinary dry-mounted preparation (or on one which is connected with the slide, the cover-glass being put on dry), and repeat the observation; you will now see again a well-defined circle, a cross-section of the emergent pencil, but of *less* diameter than in the former case, surrounded by a dark annulus, visible by faint diffused light only.

The diameter of the emergent pencil in both these experiments may be accurately *measured* if the "auxiliary Microscope" of the author's apertometric apparatus is used with an eye-piece micro-

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† See this Journal, ii. (1879) p. 267.

meter. The proportion of the clear openings (or effective diameters) with the object in balsam or in air may thus be strictly ascertained. If the objective should be rated at, say, 1·20 num. ap., the ratio of the diameters will always be found 6 : 5 (i. e. as 1·20 to 1·00); and if, in another objective, the num. ap. should be 1·40, this ratio will always be as 1·40 to 1·00 or as 7 : 5.†

The interpretation of this experiment is plain. In focussing an immersion objective on an object with air above, it is obviously converted into a true dry lens, the under surface of the covering-glass acting as the plane front-surface of the system. If the covering-glass is very close to the object the distance of the radiant from the plane surface will be so small that an exceedingly small central portion of this surface is sufficient for admitting to the front all rays up to an obliquity of 88° to 89°. The objective then acts as a dry lens of nearly 180° aperture-angle, and gathers-in almost the whole hemisphere of light from the radiant in air; whilst the same systems when focussed on an object in balsam, admit no wider cone (in the examples mentioned in the preceding paragraph) than 108° or 138°, in fact much less in each case than a hemisphere. Nevertheless, the emergent pencil of rays is much *narrower* with the whole hemisphere of rays in air than it is with the smaller cone of rays in balsam, *whilst the amplification of the image is not increased*—the power of an optical system of any kind whatever being exactly the same, whether there is refraction or no refraction at its anterior *plane* surface.

Every one will concede that there is a true reduction of *aperture* when a brass-stop is inserted at the back of a given system, stopping off a certain marginal zone of the clear opening which

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† According to the general proposition (7) the linear diameter of the *reduced* opening of an immersion glass with a dry object must be $= 2f$, provided the film of air beneath the covering-glass be very thin. By measuring the reduced opening of such an objective in the way suggested above, and taking its half, the exact focal length of the system is obtained.

The same principle may be made use of for objectives of every kind. When the numerical aperture of an objective (or the numerical equivalent of any smaller angle within the aperture-cone) is determined, and the linear diameter of the corresponding emergent pencil *at the plane of the posterior principal focus of the system* is measured micrometrically, the focal length is at once obtained from formula (7).

The author has for many years applied this very convenient and accurate method for measuring focal lengths.

On the other hand, the proposition (6) also indicates a new method for measuring apertures and aperture-angles. When the amplification N of an objective for a definite position of the image O* is ascertained, by projecting the image of a stage-micrometer upon an eye-piece micrometer, the auxiliary Microscope may be focussed to any convenient plane and the linear diameter 2ρ of the emergent pencil measured there. If now the distance l of that *same* plane from the image to which the amplification N relates, is measured likewise, we have all the elements for computing the strict value of $a = n \sin u$—and of the angle u also—by means of formula (6). This method enables us to measure immersion-apertures without requiring a disk of glass or similar devices.

was formerly utilized by the image-forming rays.† It must also be a *true* reduction of aperture when, in any way whatever, the emergent pencil is changed *as if* such a brass-stop had been inserted, provided the power of the system is unaltered. Consequently we have *loss* of aperture when an air-angle of 180° is substituted for a balsam-angle of, say 100°.

An immersion objective of balsam-angle exceeding twice the critical angle has therefore a *greater aperture* than any dry lens can ever have.

V.—*Different Angular Distribution of the Rays in different Media.*

The definition of aperture as *relative opening*, developed in the foregoing discussion, is, it is seen, the only one which is justified by the original sense of the term, and it is a point of special importance that it should be understood that the definition is not a matter of mere terminology, but that the very *essence* of the idea of aperture is involved in the notion of opening, and that there is no other reasonable base for grasping this essence. In whatever way the idea of aperture may be defined, the actual *significance* of that element in the Microscope can only be appreciated by taking into account the image-forming pencil *emergent* from the objective, and the change in its diameter consequent upon the admission of different cones of light. This diameter affords a visible indication of the *number of rays* (not mere *quantity of light* photometrically) which are collected to a certain area of the image, *and which consequently must have been gathered-in by the lens from the conjugate area of the object.* If, in any case whatever, the diameter of the emergent pencil is seen to be increased, whilst the amplification of the image and the distance of its projection (or, more generally speaking, the focal length) are unchanged, it is clear that the system must have admitted *more rays* from every element of the object, because it has collected more to every element of an *equally enlarged* image. It would be an obvious physical absurdity to declare that in any case a lens could emit more than it has taken in. *Consequently we get a true measure of what is admitted by a system by estimating what it emits.*

Thus the essential idea of aperture (which means the greater or less capacity of objectives for gathering-in rays from the objects) necessarily leads to the estimation of apertures by the *openings* of the systems.

As long as we have the radiant in one and the same medium,

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† If it should be objected that in wide-angled immersion glasses the marginal zone does not transmit image-forming rays, every one may satisfy himself at once by a simple practical trial that in a well-corrected objective all emergent rays up to the edge of the clear opening *are* image-forming rays.

the increase of the *admitted* rays with increased *opening* is very simply accounted for. We *see* the additional portions of the solid cone from the radiant, which correspond to the additional portions of the enlarged opening. But if in any other case (for instance, when the medium is different) we see that a certain solid cone A from a radiant is transmitted through a certain opening a, and that another solid cone of rays B cannot be transmitted through the same opening a, but requires a wider one β, *whilst all other circumstances, except those of the radiant, have remained the same*, we can of course only conclude that the pencil B must contain rays which are not contained in A, even if the admitted cone is not increased in size. For the additional portion $(\beta - a)$ of the wider opening β conveys rays to the image which are certainly not conveyed by the smaller opening a. Whence can this surplus come if *not* from the radiant? Obviously the pencil B, which requires the additional opening, must embrace *more* rays, even if it should not be of greater *angle*.

Now the fact is, that a given objective may collect the rays from a radiant *in air* almost to the entire hemisphere (as, for instance, in the case of an immersion lens when focussed on a dry-mounted object close to the covering-glass) and it then utilizes a definite opening, double its focal length. But when the radiant is in balsam (without any other alteration), the same opening is seen to be utilized by the rays which are within a smaller cone of not more than 82°, and rays which are outside this cone require a surplus of opening, which is never required for rays in air. This holds good, as has been shown, whether there be refraction or no refraction at the front surface of the system; the difference is based *solely* on the difference of the medium. Consequently we arrive at the conclusion that the solid cone of 82° in balsam embraces the same rays which in air are embraced by the whole hemisphere; and every wider cone in balsam, exceeding the 82°, conveys *more* rays from the object than are admitted by the whole hemisphere of radiation in air.

The definitive inference from the foregoing consideration is obvious. There is no way of reconciling the seeming contradiction between these two facts, (a) that a cone of $> 82°$ from a radiant in balsam embraces *more rays* than a cone of 180° from a radiant in air, and (b) that the *angular* extension of the former cone is less than that of the latter, except by admitting the physical fact that the *same* rays which in air are spread over the whole hemisphere, are closed together, or compressed, in balsam within a narrower conical space of 41° around the perpendicular; and all rays which travel in balsam outside this cone constitute *a surplus of new rays, which are never met with in air, that is, are not emitted when the object is in air.*

There are various direct proofs that the *angular* distribution of the radiating light is changed whenever the medium of the radiant is changed. The rays which emanate from a given object in different media are not, it is true, numbered like the sheep of a flock, and it is impossible therefore to show the identity or non-identity of certain rays under different circumstances without having first established an express *principle of identification.* This will be required for the view above expressed just as well as it would be required if any one should try to prove the (assumed) indifference of the medium in regard to radiation. There is one particular case, which however is of considerable importance for the Microscope, in regard to which such a principle may be readily established.

When a preparation contains transparent (perfectly pellucid) portions, the depiction of which yields the outlines of the non-transparent elements in the microscopic field, the rays emitted from such portions are purely *transmitted* rays. Every ray emanating from a transparent element of the object is the direct continuation of *one* distinct ray which is thrown upon that element by the illuminating apparatus. Suppose now an object of this kind, having a perfectly flat upper surface, and connected to the slide, in the one case uncovered, in the other case mounted in water or balsam under a cover-glass, and illuminated by means of an immersion condenser which collects a pencil of not less than 82° (measured within the slide) upon every point of the microscope-field. In both these cases one and the same transparent element will send into the objective, by virtue of transmission, the *same* incident rays; but when the object is in air, these same rays are distributed above the object in a different manner to that which obtains when the object is in water or balsam. In the former case all rays which are embraced by an incident cone of 82° within the glass slide make up the whole hemisphere; whilst with water above, the *same* rays are contained within an emergent cone of 96°, and with balsam within 82°.

Under the circumstances in question, those rays transmitted through the object are of course *identical* rays—notwithstanding their different directions in air, water, or balsam—which are the continuation of identical incident rays. In regard to that kind of radiation, therefore, on which the delineation of the *outlines* of non-transparent or semi-transparent objects is based, a pencil of 82° in balsam or of 96° in water, conveys the same rays to the Microscope as the whole hemisphere in air, and there is a different angular distribution of the radiating light in different media. In this case the *causa efficiens* of the phenomenon is, of course, the different refraction with which the transmission is connected. A dioptrical explanation of the varying distribution does not, however, change the fact that there *is* such distribution.

A *general* criterion of identical and non-identical rays in different media, which applies to every kind of radiation and leads to the same conclusion, is obtained when we refer to the *physical* notion of a ray. Physical optics defines "rays of light" as the orthogonal trajectories through a system of waves. The principle of this definition implies, at the same time, that "homologous rays" in different wave-systems are to be determined with regard to the rate of propagation in these systems; and it is found that homologous rays are *closer* together when the velocity of propagation is *less*, and *vice versâ*—in perfect analogy to the "lines of force" in a magnetic or electric field when the electric or magnetic charge is increased. The direct outcome from this is, that identical rays emanate under smaller angles of obliquity in a medium of higher refraction, and, in general, one and the same system of rays constitutes cones of different angles in air, water, or balsam, in such a way, that the "numerical" equivalents of these various cones (the product of the *sine* of the semi-angle by the refractive index) are always the *same*.

This theoretical inference bears directly on that kind of radiation which is the most important one for the Microscope—the radiation of objects by *diffracted* light. Every structural object, whether the structure is regular or in any way irregular, which transmits or reflects a narrow-angled incident beam of light (or any number of such making together a wide-angled cone) changes this beam (or each one of the several beams) into a wider or narrower *pencil*, with varying intensity in different directions, by virtue of diffraction. The interference of elementary waves emitted from the transparent or semi-transparent elements of the structure neutralizes the undulatory motion above the object in some directions, whilst in other directions the survival of the motion, or of a fraction of it, develops rays of light of various intensities, which emanate from the object in various directions as if it were self-luminous. In the case of regular *periodic* structures, as lined objects, diatoms, &c., the diffraction pencil originating from an incident beam appears as a fan of isolated rays of decreasing intensity around the direction of the incident beam transmitted through the structure—the interference of the primary waves yielding in this case a number of successive maxima of light with dark interspaces. According to the well-established laws of the diffraction phenomenon, the fan of diffracted beams from one and the same structure is spread out under a wider angle when the wave-length of the medium is increased or the refractive index is diminished, and is more compressed together in the opposite case; in such a way, that the *sine* of the angle of obliquity of the *same* beams—for instance, the first, or second . . . maximum—is changed in the inverse ratio of the index. Owing to this, one and the same solid cone at the object will embrace a larger number of diffraction beams in balsam than in air; and if the elements of the structure are very minute a solid cone exceeding in balsam the angle of 82° will contain beams which do not exist at all when the same structure is in air, because they cannot be originated except with waves of *shorter* length than are in air.

Experiments, which have been fully described, demonstrate *ad oculos* the admission of these beams of diffracted light to the Microscope and the *effects* which are attendant upon the admission of more or less of them in regard to the microscopical image. It is shown that the diffracted light emanating from the objects may utilize the *whole* aperture of a system, although the incident cone of light, if it were simply transmitted (in the absence of an object), would fill only a small portion of the aperture. In particular it may be seen experimentally, that with a narrow illuminating pencil a wide-angled immersion glass may gather in, and collect to the image, rays from an object in water or balsam, which are not met with in the whole hemisphere when the object is in air, and consequently can never be utilized by a dry lens of any aperture-angle whatever.

Owing to the general principle of physical optics mentioned above, homologous diffraction beams from one and the same structure—for instance, the first, or second . . . maximum in the case of a periodic structure—are the *same* rays *physically*, notwithstanding their different obliquity, and diffraction beams which show the same obliquity in different media are *different* rays *physically*. Thus the phenomena of diffraction in the Microscope afford another experimental proof of the validity of the inference from the principle of the aperture-equivalent: *that there is an unequal angular distribution of radiation in different media, and that a given solid cone from a radiant in balsam may contain more rays than the same cone from a radiant in air, because the same rays are closer together, and others are introduced.*

The above considerations lead to the following conclusions:—

(1) The unequal equivalent of equal aperture-*angles* indicates a different *number of rays*, as conveyed by *equal* cones in different media consequent upon a different *density* of radiation in such media; and this is quite distinct from any photometrical estimation of the *quantity of light* in these cones, which may vary independently according to the illumination of the object, the change of its surface by different media, &c.

(2) An aperture-cone exceeding twice the critical angle of the medium to which it pertains, embraces a surplus of rays which do not exist, physically, when the object is in air, because they are *not emitted into air*. A wide-angled immersion glass, therefore, may utilize rays from an object in

> a denser medium, which are entirely *lost* for the image—which, in fact, do not exist—when the same object is in air or is observed through a film of air. *This loss can never be compensated for by increase of illumination*, because the rays which are lost are *different* rays, physically, to those obtained by any illumination however intense in a medium like air.

It is not surprising that a notion of aperture—the *angular* notion—which is so incomplete and so misleading in regard to the most characteristic feature of the performance of the Microscope should have been abandoned. Adhering to the angles merely, and disregarding the influence of the medium, has entirely concealed from many microscopists even those plain truths which have long ago been settled by the *practical* use of the instrument. Inasmuch as the experience of two decades has established beyond any doubt the fact, that immersion objectives readily depict minute structures which are not shown by the most perfect dry lens, *whatever may be the illumination*, it is strange that it can still be supposed anywhere at this day that the true advantage of the immersion method cannot be anything beyond greater convenience in regard to working distance and some (very moderate) gain of light from the abolition of front-reflection—*because* the aperture-angle of these objectives cannot be greater than with dry lenses.

If any person, who agrees that a rational definition of aperture can only be established on the basis developed here, should yet dislike the expression "*numerical* aperture"—for any reason whatever—I certainly do not object to another term, if a *better* can be found. In point of fact, I was obliged to introduce this term for the mere sake of preventing confusion. It is in reality objectionable, as the word "numerical" conveys the idea that a *particular* description of aperture, among others on an equal footing, is intended to be denoted. From my point of view, the aperture-equivalent should be called "aperture" *sans phrase*, because it *is* "aperture *sans phrase*."

VI.—*The Photometrical Equivalent of different Apertures.*

Difference of aperture must of course always correspond to a different *quantity of light* admitted to the objective, provided all other circumstances are equal; and thus the question of aperture has necessarily also a photometrical aspect which leads to the consideration of the *photometrical* equivalent of different apertures or aperture-angles. But it is clear that this point of view does not meet the real essence of the aperture problem. The brightness of the image (which of course *alone* will depend on the photometrical equivalent) is certainly a matter of practical importance in the Microscope; but if a greater aperture signified nothing more than greater quantity of light—if there were no *specific* difference of the rays which can be utilized by different apertures—the whole question would be only of somewhat subordinate interest. More light *from* an object can always be gained when more is thrown *upon* the object by means of a brighter source of illumination.

Inasmuch, however, as the determination of the photometrical equivalents of different apertures affords an additional *illustration* of numerical aperture, it will be useful—for the sake of completeness merely—to add a brief outline of the photometrical principles relating to the matter, though nothing can be said here which has not been established long ago.

(1) In the last century Bouguer† and Lambert‡ established the important fact that with any surface of *uniform radiation* (so called) the intensity of the emitted *rays* is *not* the same in all directions. The *power of emission* and the intensity of the rays (i. e. the quantity of light emanating from a given surface-element within a cone of a given *narrow* angle) varies in the proportion of the *cosine* of the angle of obliquity under which the ray is emitted. This proposition is nothing more than the expression of the simple fact, that a surface of uniform radiation shows the same visual brightness in all directions; and that such a surface, if curved (for instance the sun, or the porcelain shade of a lamp, &c.), is always seen projected as a surface of *uniform brightness.*

This theorem, which at a later period was confirmed by Fourier, Melloni, and other physicists, shows at once that the quantities of light emitted from one and the same object within solid cones of different angles are *not* in the ratio of these solid cones, but in the ratio of the squares of the *sines of their semi-angles.* Thus the whole emitted light (embraced by the entire hemisphere of radiation), and that portion which is emitted within a cone of 30° around the perpendicular (or 60° angle) are not, as is so constantly assumed, in the ratio of $7 \cdot 46 : 1$ (as the solid cones in fact are), but in that of $4 : 1$ only.

As in one and the same medium the number of rays conveyed by a pencil and the photometrical quantity of light are proportional, this old-established Lambert theorem is sufficient of itself for overthrowing the very basis of the *angular* expression of aperture, and for proving that even when we are dealing with one and the *same medium* only, the *angle* is not the sufficient expression, but that it is the *sine of the semi-angle* which must be taken.

(2) In more modern times, but still seventeen years ago, a distinguished physicist, well known in England, R. Clausius, established by a famous research "On the Concentration of

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† 'Traité d'Optique sur la Gradation de la Lumière,' 1760.

‡ 'Photometria,' 1760.

Calorific and Luminous Rays and the Limits of its Efficiency,"† another proposition pertaining to radiation in *different media,* viz. that the *power of emission* of a body—in regard to heat as well as to light—is not the same in different media, but varies in the ratio of the squares of the refractive indices, so that the *whole* emitted light from any surface-element of a self-luminous body is increased in the proportion of $1 : n^2$ when this body is brought from air into a denser medium of refractive index n. If a glowing body at a constant temperature, such as a bar of iron, could be immersed in a medium of 1·5 refractive index, in such a way that the surface were in optical contact with the medium, and the eye of an observer immersed likewise (the diameter of the pupil being kept unaltered and the loss of refraction at the cornea compensated for), the body would be seen *brighter in all directions* in the proportion of 9 : 4 than it appeared in air.

The principle of Clausius applies also to the diffused radiation of non-self-luminous bodies, provided their internal structure and surface are not changed by the surrounding media. An object which fulfils this condition (without which of course there could not be a constant illumination)—for instance, a polished plate of porcelain glass—gives out by diffused reflection or by diffused transmission a *greater portion* of the incident light, if the radiation takes place into oil or in any other dense medium, than when it takes place into air as can be shown by a simple experiment.‡

The principle of this varying emission in different media is not so far from a rational explanation as it may appear on a superficial consideration. "Quantity of light" is the energy of an undulatory motion. A "constant illumination," or equal intensity of radiation, means equal *amplitude* and equal *frequency* of the undulation at the radiating surface. These circumstances being equal, the amount of undulatory energy which is transmitted by the waves to any definite surface (for instance, to the whole surrounding hemisphere) must depend on the *density* of the propagating medium which is excited by the primary motion—because the *vis viva* of *every single wave* of given amplitude is greater in the proportion of this density. In fact, the stroke of a bell or the human voice is found to give a louder sound in the dense atmosphere at the level of the sea than in the rare air on high mountains. According to the theory of Fresnel, the relation of the

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† "Ueber die Concentration von Wärme- und Lichtstrahlen," &c., Pogg. Annalen d. Physik, cxxi. 1864.

‡ The author has furnished to Mr. Crisp a little piece of apparatus for demonstrating *ad oculos* the fact, that a thin polished plate of porcelain glass illuminated from the back, throws, from a given area, an evidently greater quantity of light into a block of crown glass (cemented on), than an equal area of the same plate under exactly the same illumination throws into air.

densities of any two media in respect to the propagation of luminous waves is expressed by the *squares of the refractive indices* of these media.†

(3) Further, in 1874 another well-known and distinguished physicist, Helmholtz, confirming certain propositions of the author which were directed to the same subject, demonstrated ‡ a similar principle pertaining to the photometrical equivalent of the pencils of light which travel from a luminous object through different media *successively*. In this case the quantity of light conveyed by *equal* solid cones is also in the ratio of the squares of the refractive indices of the media.

From these established theories of photometrical optics it is seen that the *quantity of light* emitted from an object under a given illumination is *not* measured by the angle of the emitted cone at the radiant, nor can it be measured in any way by means of the angle *alone*. The quantity depends under all circumstances on *the product of the sine of the semi-angle and the refractive index of the medium in which the object emits*, and is expressed by the square of this product, or by the square of the "numerical" aperture of the pencil.

Thus it is shown that the *general* aperture-equivalent, which is defined by the value of a, indicates at the same time the *photometrical* equivalent of different apertures.

The practical outcome, as regards microscopical vision, of this photometrical inference is the general proposition of the *illuminating power* of the Microscope, or the brightness of the microscopical image, first propounded in the author's paper of 1873,§ and in that of Professor Helmholtz quoted above:—

If the losses of light by reflection and absorption in an optical system are disregarded, the brightness of the microscopical image under a given illumination of the object depends *solely on the linear diameter of the transmitted pencils of light at their emergence from the ocular,* and is always the same when this diameter is the same, whatever may be the composition of the Microscope (objective, eye-piece, &c.) and the amplification of the image. The diameter of the ultimate emergent pencil, or the cross-section of this pencil, is *visible* within the so-called "Ramsden circle" above the

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† The supposition of *cold* and *hot* air would render the accordance of the circumstances of the acoustical and the optical phenomena still more complete. But as, under the point of view in consideration, the *causa efficiens* is the density of the medium, and not the velocity of propagation, the difference is immaterial.

The above popular elucidation of the principle is not, of course, intended as a scientific demonstration. It is only given for the purpose of showing that common sense is by no means on the side of opposite opinions. The demonstration of Clausius, moreover, does not depend on the hypothesis of Fresnel nor on any other assumption which can be a matter of dispute among physicists.

‡ "Die theoretische Grenze für die Leistungsfähigkeit der Mikroskope," Pogg. Annalen d. Physik, Jubelband 1874, p. 564.

§ Arch. f. Mikr. Anat., ix. (1873) p. 438.

ocular. When this diameter is greater than, or at least equal to, the diameter of the eye's pupil, the brightness of the image has its *maximal* value, which can never be increased, and is the same brightness which would be obtained with direct vision by the naked eye, of any large object under the same illumination; and when the ultimate diameter of the emergent pencil is the kth part of the pupil's diameter, the brightness of the image is the k^2th part of the brightness of unaided vision.

Denoting by Δ the conventional distance of distinct vision, by N the linear amplification of the image projected to this distance, $\frac{\Delta}{N} = \phi$ will be the equivalent focal length of the total Microscope. If then a is the numerical aperture of the admitted pencil (which may utilize either the whole aperture or a part of it only), the diameter δ of the ultimate emergent pencil at the plane of the Ramsden circle will be according to proposition (7) of Sec. I.

$$\delta = 2\,a\,\phi,$$

which is the diameter to be compared with that of the pupil in order to obtain (by the squares) the ratio of the brightness of the microscopical image to the brightness in vision with the naked eye.

The different *photometrical* equivalent of equal angles in different media, may be plainly demonstrated by several observations which are already well known, and within the reach of every microscopist, but I may briefly indicate some of them here.

(1) Objects are seen with *equal* brightness, with the naked eye and with the Microscope, whether they are uncovered or protected by a covering-glass cemented on, provided their pellucidity is not changed by the surrounding medium. (No such change takes place, for instance, with perfectly transparent portions or elements of a preparation.) It is evident that the pupil of the eye, or the objective of the Microscope, admits from every radiant in air a *wider angular* pencil than from the radiant in balsam, as the latter pencil acquires the angular width of the former by an *expansive* refraction at the surface of exit. The diameter of the object under the covering-glass is not of course reduced by this refraction, but appears of the same size still, and consequently the narrower pencils emanating from the object in balsam must convey the *same quantity* of light as the broader pencils emanating in air.

(2) When a hemisphere of glass is cemented to a preparation and the condition above referred to is fulfilled, the object appears just as bright as it appeared uncovered, as well with the Microscope as with the naked eye. In this case the divergence of the pencils at their exit into air is not changed, and the pupil of the eye or the lens-opening receives equal pencils under both circumstances. But as the hemisphere amplifies the object at its centre in the

proportion of 3 : 2 linear, and the surface in the proportion of 9 : 4, it consequently *gives out* from every square millimetre of the object as much light as is given out in air from 2¼ square millimetres. Consequently the quantities of light conveyed by equal solid cones in balsam and in air are in the proportion of 9 : 4.

If equal angles at the radiants in both media indicated equal quantities of light, the object *under the glass* ought to appear less bright (in the proportion of 4 : 9) in *both* these experiments.

(3) A third fact exhibits the exact converse of the preceding. Suppose a surface, for instance a sheet of white paper, illuminated by a source of light at a given distance. It will show a certain illumination. Putting on now a hemisphere of glass, that part of the paper which is near the centre of the hemisphere will show an evidently brighter illumination. The visual angle of the source of light from that place is certainly not changed; the solid cones which converge to every one point of the paper are exactly the same still. If, nevertheless, more light is collected to every square millimetre under the hemisphere, the solid cones in glass must convey more than equal cones in air.

The *concentration* of the incident rays at the centre of a hemisphere, is, of course, fully accounted for on the ordinary dioptrical principles—just as the amplification of an object at the centre is. There is nothing mysterious in these observations, but the dioptrical explanation does not alter the *fact*, that there *is* an unequal quantity of light corresponding to equal cones in different media.

VII.—*Relation of the Aperture-equivalent to the general "Delineating Power" of the Microscope.*

The notions of "more" and "less" in regard to the number of rays admitted to different systems, and the conclusions based thereon, are, it will be seen, quite independent of (and much more general than) mere photometrical estimations of quantities of *light*, which of course would relate only to a difference of *brightness* in microscopical images. Nor are these conclusions in any way dependent upon the author's theory of microscopical vision, though the phenomena of diffraction have been adduced above as *one* illustration and experimental support of the general principle. This principle has no *essential* connection either with any particular physical process from which the radiation of microscopical objects may result, or with the laws on which the delineation of the microscopical image may depend. The question so far has not been, whence *come* and how do those surplus rays act, which are utilized by means of a given balsam-angle, in comparison with an equal air-angle, but whether there *is* such a surplus. When *this* is once settled, the preponderance of the former angle over the latter is settled also. For it will be conceded that an objective of 120° air-angle shows more than an objective of 60°, and that it does so *because* it admits *more rays* than the latter. Nobody can deny, then, that a system of 60° balsam-angle must have the same preponderance over the system of 60° air-angle, because *it also* admits more rays—quite apart from the question, *why* does a lens show more if it admits more rays?

At the same time, however, it will not be without interest to refer here to the considerations which show how the subject of aperture in the Microscope becomes one of *general* practical importance.

It is evident that the increase of the aperture-equivalent would not be the basis of progress in the performance of the instrument, if there did not exist a *general* cause by virtue of which such wide apertures are *utilized.* Now, it is quite certain that the illumination of the objects by wider incident pencils of light, does *not* afford such a general utilization. In the practical use of wide-angled objectives, we are for the most part confined to an illumination by rather narrow pencils, which occupy only a *small* portion of the aperture-cone. If we throw upon a delicate object a cone of light sufficient to fill the whole aperture of such a system (which of course *can* always be done by means of a suitable illuminating apparatus) we should in most cases see nothing, or next to nothing. Wide-angled glasses, as is well known, show more than narrow-angled, *although* the direct transmitted rays from the illuminating pencil utilize a small portion only of the clear opening; and in many cases show the more, the more the incident pencil is reduced. Consequently, another reason is required in order to account for the fact, that there *is* a general benefit with the wider aperture.

With regard to rather *coarse* objects, which are perfectly delineated by low-power and narrow-angled lenses, we find several effects which produce an angular expansion or dissipation of the incident pencil above the object—particularly deflections of the transmitted rays by prismatic or lenticular action of the elements. *These effects, however, do not continue* when we have objects with *minute* detail of any kind. Theory and observation unite in the conclusion, that spherical, cylindrical, or prismatic elements not exceeding a few wave-lengths in diameter cannot yield and do not yield anything like lenticular or prismatic deflections.† Whenever

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† By way of example I may refer to the phenomena of the valve of *Pleurosigma angulatum* first pointed out eight years ago. The more general opinion among microscopists is that it is composed of spherules. Inspect now *through* such a valve a bright well-defined luminous object and observe the optical effects of the spherules on the transmitted rays. Notwithstanding the minuteness of the diatom, this may be readily done. With an $\frac{1}{8}$ objective, focus a good specimen at the centre of the field, and after having withdrawn the ocular, bring the pupil of the eye on the air-image of the valve as projected by the system. You will then see the illuminating flame or the clear diaphragm-hole of the condenser *through* the valve, because no ray can reach the eye, which has not passed through that

the details of a structure are so minute, that wide-angled (or even moderate angled) systems are *required* for its delineation, there remains only *one* reason which accounts for a radiation of the object in other directions than those embraced within the incident pencil, and that is the *diffraction* of the light by the structure. By virtue of the diffraction effect attendant upon the transmission or reflection of light by any structure (whatever may be its composition) the incident beams are scattered over a larger or smaller part of the hemisphere above the object; and *thus* a radiation is obtained which, in the case of very minute elements, may fill the whole hemisphere (even in a dense medium), and utilize any wide aperture. Owing to the diffraction effect, microscopical objects radiate, in a certain sense, in the manner of self-luminous bodies, and this the more so as their elements become smaller and smaller. What is generally (and erroneously) called "diffused" radiation of microscopic objects is—with the exception probably of a few particular cases which have no practical importance for the Microscope—nothing else but radiation by means of diffraction beams expanding the incident pencils above the object.

From this point of view a proper estimation of the *actual* importance of aperture in the Microscope, and of the *practical* value of a correct definition of apertures, is entirely based upon the consideration of the phenomena of diffraction in the Microscope. All aperture-equivalents or aperture-angles beyond a very moderate extent would be meaningless and dead things, if there did not exist a general physical process by virtue of which the objects *emit* those rays which *can* be admitted by wide apertures. At the same time it is evident that the original idea of aperture as the capacity of an objective of gathering-in rays from the objects, means but *one* function practically, that of gathering-in a greater or less portion of the *diffracted rays* scattered by the objects. There cannot be any other general benefit of large apertures, because there is no other general cause of a dissipation of light by the objects without which the utilization of wide-aperture cones would not be possible. Diffraction, however, is universal whenever the strictly uniform propagation of luminous waves (transmitted or reflected) is disturbed by the interposition either of opaque or semi-opaque

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portion of the valve which is optically conjugate to the area of the pupil. Provided the mid-rib is not just projected on the eye, the flame or the diaphragm-hole is seen as well defined as if through a plate of glass; you do not see the least deflected or scattered light *except* the bright diffraction spectra arranged around the direct image.

Whilst it is not *my* opinion that the *angulatum*-valve is composed of spherules, yet even if such should exist, they would not have a different effect. We may infer from observation and from theory, that very *minute* spherules, or cylindrical threads, have entirely lost the characters of *refracting* bodies, which are so distinctly exhibited by air-bubbles, fat-drops, &c., of *larger* size. The residual effect of such objects is solely retardation or acceleration of the transmitted waves, by virtue of the *difference* of their own refractive index and that of the surrounding medium; and this is *one* among the conditions of *diffraction.*

elements, or of transparent elements of unequal refraction, which originate unequal retardations of the waves.

Bearing in mind what has been said above (Sec. V.) in regard to the different angular expansion of *homologous* diffraction fans in different media, and remembering that this holds good for *every* kind of diffracting structures, whether of regular or irregular composition, it will be easily seen that whilst numerical aperture indicates the relation of opening and focal length, it also indicates at the same time the true equivalent of different apertures in regard to the smaller or greater portion of the diffracted light, from any given structure, which an objective *can* admit and collect to the image.

The practical importance of the admission of more or less diffraction beams in regard to the image which is depicted by an objective has been shown already by many experiments with various microscopical preparations. Experiments of this kind must, of course, be confined to those structures which permit the direct observation of the diffraction beams and of the influence exercised by their admission or exclusion. This is the case only with regular periodic structures composed of a multitude of similar elements, because these alone yield *bright* and *distinct* diffraction spectra, composed of isolated well-defined portions of light with characteristic colours. Irregular structures, or objects composed of a few elements only, produce diffraction effect also, with no less angular expansion of the rays, but these do not yield distinct spectra nor sufficiently bright beams for convenient observation. The experimental investigation of the subject must therefore be confined to that *particular* action of the aperture-function in the Microscope, which is exhibited in the delineation of lines, striations, field-markings, and similar regular structures, and is known as the "resolving power" of objectives. The study of this particular exhibition of the diffraction phenomena, and of their influence on the microscopic image, affords, however, at the same time an exemplification of the aperture function in its *general* features. It is shown in this way that the admission or exclusion of different portions of the diffraction pencil emanating from an object *can* have a real influence on the image which is delineated, because it *has* such influence, as a matter of fact, with certain kinds of objects.

As, therefore, the *practical* value of increase of aperture is the increased admission of diffracted light from the objects, it is a matter of special importance, for the due appreciation of aperture from this practical point of view, to have a clear answer to the question, *What* is the benefit of this increased admission in the *general* performance of the Microscope, apart from the delineation of lines and field-markings in diatoms and similar objects, which may be said to be of interest only to a few? The definitive outcome of the author's investigation into this subject is fully developed in another paper.† In order, however, to give here a summarized idea of the benefit attendant upon increased aperture, and to indicate *what* it means for the general interest of microscopical vision: difference of the diffracted light which is utilized for the image—I briefly point out here some propositions which are established by theory and experiment in that paper:—

(1) *Perfect similarity* between the microscopical image and the object, or a true enlarged projection of the object by the Microscope, *always* depends on the admission to and utilization by the objective, of the *whole* of the diffracted rays which the structure is competent to emit.

(2) Whenever a portion of the total diffraction fan appertaining to a given structure is *lost*, the image will be more or less *incomplete and dissimilar* from the object; and in general, the dissimilarity will be the greater the smaller the fraction of light admitted. In the case of periodic structures, the exclusion of all diffracted rays, except the central (direct) beam of the diffraction fan, will entirely obliterate the details of the image. With structures of every kind (periodic and irregular) the image will lose more and more the indications of the minuter details, as the peripheral (more deflected) rays of the diffraction spectrum or diffraction pencil are more and more excluded.

For example: When a striation, a grating, or a diatom is close to the limit of the delineating power of a given aperture (i. e. when the distance of the lines is not much greater than $\frac{\lambda}{2a}$) the image is always depicted by *two* diffraction beams only (if with bright field, by the direct, undeflected ray, and *one* spectral ray). In this case the striation always appears as if the darker and brighter interspaces composing the striation were very approximately of *equal* breadth, although the inspection of a *more complete* image of the same structure, obtained by means of a much greater aperture, should show the proportions of the alternate striæ to be *very* different.

Another example: The diffraction fan of isolated corpuscules or threads (say bacteria or cilia), in a clear field, must be exactly identical to that of equal-sized holes or slits of equal shape in a dark background, and there must be (as theory shows) a continuous and nearly uniform dissipation of diffracted light over the whole hemisphere, provided the diameter of the object is very small (a fraction of λ); and this would be so even in a medium of highest known refractive index. Such objects *can* be seen, however minute they may be;

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† 'Die Grenzen der geometrischen Optik in der Theorie des Sehens und der optischen Instrumente.' (The limits of Geometrical Optics in the Theory of Vision and Optical Instruments.) 8vo. Jena, 1881. (In the press.)

this is merely a question of contrast in the distribution of light, of good definition in the objective, and of sensibility of the retina.† But whenever they *are* seen, they are seen *increased* in size, owing to the loss of diffracted light in every medium whose refractive index is not a considerable multiple of the unit. Similar objects of larger diameter—say 10 λ—are delineated of their *exact* size, by objectives of perfect definition, because the diffracted light in this case is not, even in a medium like air, subtended far from the direct beam in perceptible intensity, and the *whole* can be admitted therefore with a moderate aperture.

> (3) When a portion only of the whole diffracted light from a structure is utilized, the image is a true enlarged projection of a *different* structure, namely of one the *whole of whose diffracted beams* would (if it physically existed) be represented by the *utilized* diffraction beams of the structure in question.

For example: If *angulatum*, either in balsam or adhering to the covering-glass, is illuminated by a direct incident pencil, it is delineated with a *wide*-angled immersion glass by means of the direct undeflected beam and six surrounding spectral beams. The image which is then seen is not a true copy of the real (quite occult) structure of the valve; but it is a true enlarged projection of *that* structure which (if it could be produced artificially) would break up by its diffractive power an incident beam into a fan (or more strictly "group") composed of the direct ray and the said six deflected rays, *and these alone*. If we illuminate the valve by an oblique incident beam, some of the six spectra are shut-off by the margin of the aperture, and one or two new ones of greater deflection (which remained outside the aperture in the former case) are taken in if the aperture is sufficiently wide. The *effective* portion of the diffraction group is now very unsymmetrical. The image which is *now* seen is the true projection of that *other* structure which would yield this unsymmetrical group as the *whole* of its diffraction effect, such group being identical both in the number and brightness of its beams to the admitted beams.

The great variety of aspects which are obtained from one and the same object merely by change of illumination, is fully accounted for and defined by the above proposition.

Or as another example: A very thin thread—say a minute cilium—only a fraction of λ in diameter, is depicted with considerably increased diameter, even with a very wide aperture. The image is the *true* copy of *another* thread (the composition of which can be computed by theory) which would yield a diffraction fan exactly similar to that which is actually admitted by the objective, but

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† In point of fact, neither Professor Helmholtz nor the author have ever spoken (as, however, has so often been supposed) of a limit of "visibility"—only of a limit of visible "separation."

abruptly broken off at the limit of the aperture-cone (the intensity of the deflected light suddenly cut down to zero at a definite obliquity). Theory shows, that a thread-shaped object which could yield such a particular diffraction effect, must (other differences not considered) be at all events *greater* in breadth than another one yielding the full continuous dissipation of light.†

> (4) As long as all distinct elements of a structure are measured by large multiples of the wave-length of light, all diffracted rays of perceptible intensity will travel within a narrow cone around the direction of the incident beam from which they originate. In such a case any narrow aperture-angle will be sufficient to admit the *whole*. The images of such *coarse* objects (or of their coarser parts) will therefore be always perfectly similar to the object, i. e. will be *true* enlarged projections.
>
> (5) When the diameters of the elements of a structure (or of some of the elements in it) are reduced to smaller and smaller multiples of the wave-length which corresponds to the medium in which the object is, the diffraction pencil originating from an incident beam has a wider and wider angular expansion (or in other words the diffracted rays are further apart); and when this diameter is reduced to a few wave-lengths, not even the hemisphere can embrace the *whole* diffraction effect which appertains to the structure. In this case the *whole* can only be obtained by shortening the wave-length, i. e. by increasing the refractive index of the surrounding medium in such a degree that the linear dimensions of the elements of the object become a large multiple of the *reduced* wave-length. With very minute structures, the diffraction fan which can be admitted in air, and even in water or balsam, is only a greater or less *central portion* of the whole possible diffraction fan corresponding to those structures and which could be obtained if they were in a medium of much shorter wave-length. Under these circumstances no Microscope, however wide may be its balsam-angle, can yield *a complete or strictly similar image.*

These propositions relate to structures of all kinds, whatever may be their physical and geometrical composition—isolated elements of any shape not excluded; they embrace the totality of the objects of microscopical research.

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† The theory of diffraction if developed on a more general basis shows that a structure may always exist which is competent to originate as the *whole* of its diffraction effect any given, even discontinuous or abruptly broken off, diffraction spectra, for instance that portion of the actual diffraction spectra of another structure which remains after excluding a certain other portion. Such discontinuous spectra are not obtained with structures (as an ordinary grating) whose diffraction effect is solely based upon *interception* of the rays by varying absorption. They are, however, obtained with structures which occasion at the same time varying *retardation* of the transmitted waves owing to unequal thickness or unequal refractive index of the transparent elements.

They establish therefore a most general signification of the aperture-equivalent. The value of a ($= n \sin u$) indicates the number of rays which an objective *can* admit. The rays which *are* admitted (in such a way that the aperture-cone is truly utilized) are greater or smaller portions of the diffraction pencils originating from the objects. *The greater or smaller the admitted or utilized portion of these rays, the greater or less similarity between the image and the object.* The aperture-equivalent measures, consequently, the very essence of microscopical performance. It *measures* the degree in which a given objective is competent to exhibit a true, complete delineation of structures of *given* minuteness, and conversely the proportion of a in different objectives is the exact measure of the different *degree of minuteness* of structural details which they can reach, either with perfect similarity of the image, or with any *equal* degree of incompleteness of the image—provided, of course, the purely dioptrical conditions of the delineation (defining-qualities, amplification, &c.) are the same.

Numerical aperture is thus the true and general expression of the "delineating power" of the Microscope.†

VIII.—*The Indifference of the Angles quâ Angles in Microscopical Performance.*

The foregoing considerations establish that from all the points of view which have been investigated, the *angle* is not the true basis of comparison for objectives. It is not so either in regard to aperture in general, as far as this idea has any relation to opening; nor is it so in regard to the number of rays (geometrically) or of the quantity of light (photometrically) which is admitted to a system;

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† In order to have a brief expression for the capacity which depends on the aperture-equivalent of objectives, the author uses the term "delineating power." The word "resolving-power," as applied in England, is too restricted in meaning; the general idea being that it aims merely at the depiction or non-depiction of striations, field-markings, and similar things. Resolving-power in this restricted sense is the *particular* exhibition of the general aperture-function on *periodic* structures, whose diffraction groups consist of a number of *isolated* beams (maxima of second order) around the direct beam (which is the maximum of first order according to Fraunhofer's terminology).

The other term "definition," by which some microscopists convey the idea of a more general optical virtue of the objectives, is better reserved—as is done in Germany—for denoting the "defining quality," or the more or less perfect collection of *all* admitted rays to *sharp* foci. This quality—which at all events requires some definite name—is based on the purely dioptrical perfection of a system (the good correction of spherical and chromatic aberration, &c.). It is exhibited by the *distinctness* of all elements in the image, *large as well as minute*, and has, of course, nothing to do with aperture. An objective may possess the best definition, but nevertheless a low delineating power, if its aperture is relatively small. On the other hand, the *actual* manifestation of a *great* delineating power, or the *utilization* of a great aperture, must evidently require *good* definition, just as it requires a certain amplification. Otherwise the minuter elements which *could* be delineated by means of the wide aperture-cone, would be obliterated by the circles of indistinctness in the image, just as they would remain *invisible* with lack of amplification.

nor is it so in regard to the very essence of microscopical performance, the delineating power of objectives. This, however, does not of course exclude the idea that there might be some *other* element in the performance of the Microscope, which does not depend on the aperture-equivalent, but rather depends on the *angle* of aperture *quâ* angle; and if such an element should be found, and should prove to be of any practical importance for microscopical vision, the angular aperture would also deserve attention. Down to more recent times there has always been an opinion among some microscopists in England that such an element exists—that there *is* something in the operation of the Microscope, in regard to which the wider *range of obliquity* of the admitted rays attendant upon a wider aperture-angle, is an advantage.

The question, whether there *is* such an *x*—which is called by the names of "angular grip," "all-round vision," and similar expressions—or whether there is not, can surely be settled at once in a purely practical way. If it be not a mere outcome of imagination, it must be possible to demonstrate it in the Microscope with actual preparations—in the same way as the increase of opening, or the increase of light, or the increase of delineating power with the greater aperture-equivalent can be shown.

There is evidently ample range for doing this. The width of the angular grip is certainly greater in a wide-angled dry lens than in an objective of 90° balsam-angle; and it is certainly cut-down more and more, when with one and the same objective preparations are observed in water, balsam, and say monobromide of naphthaline successively. If now the angles, *quâ* angles, are effective in *any* way, *something* must be *lost*, if we change the conditions of the observation in the direction indicated above, and *something* must be *gained* in the other direction, other circumstances being the same. *What* is the benefit of the complete all-round vision of a dry lens of 170° aperture-angle against a moderate-angled immersion glass, and *what* is lost by observing an object in balsam instead of air?

No microscopist has yet demonstrated this *x*. Of course, when an object whose own refractive index is not much different from 1·5, is imbedded in balsam, the radiation of this object, and particularly the intensity of the diffraction effect of its structure, is changed, and may be totally obliterated; and thus it may happen that the observation of it becomes much more difficult, or the image even entirely lost. But *such* a loss is at once recovered when we substitute for the balsam a substance of much higher refractive index, although the angle is now *still more* cut-down.

The above considerations are sufficient for establishing the non-existence of a peculiar operation of the angle *quâ* angle in the Microscope. The question may be settled, however, more exhaustively by tracing the suggestion back to its true origin. This is certainly not to be found on any grounds of observation, but rather on those of speculation and analogy. Microscopists have adhered to the angles not because a peculiar benefit from a greater range of obliquity at the object has been *found*, but because such a benefit is *supposed* to be an inevitable necessity with regard to the facts of ordinary vision. The prominences of a wall are seen more distinctly in an oblique direction, or when an oblique incidence of rays makes them project their shadows. It is *supposed* that in the Microscope a similar effect must also be connected with oblique vision and with oblique incidence of the illuminating beams, and that consequently a wider range of obliquity in the aperture-cone *must* be a benefit in microscopical vision, even though we may not be able to observe it directly. This opinion, moreover, *seems* to have a strong support in the well-established fact that in many objects we see minuter details with an oblique incident pencil than we can see with the same lens by means of direct light. Moreover, with a wider aperture-angle there is a greater *variety* of the directions under which delineating pencils emanate from the object; and it is *supposed* that the greater variety of perspective aspects which seem to combine in the microscopical image must tend to the exhibition of the structural details, and enhance the impression of *solidity* in the image in a similar way as is done by binocular vision, and the more so as the objects are closer to the observer and the angle formed between the eyes is increased. By the expression of "all-round" vision the idea is suggested that in observing objects with wide-angled lenses a hundred eyes are arranged around the preparation, and join their different views of the same object in the microscopical image. These benefits, if they exist, must, of course, depend on the angles *quâ* angles, and not on the aperture-equivalents.

These suggestions reveal a very contented view of the peculiar operations of wide apertures. But it is necessary to say that all these opinions belong to the venerable relics of the past naïve period of microscopical science, which was characterized by an unshaken conviction in the validity of the hypothesis that microscopical vision is in all essential respects the same thing as ordinary vision, that is, governed by the same laws, and based upon the same conditions as those revealed by the optical phenomena with any *large* bodies. The investigation into the subject of microscopical vision, which the author began some years ago with his friend Dr. Zeiss, and has continued ever since, at once disproved this hypothesis by the exhibition of irreconcilable facts, and proved that it is in direct contradiction to the best-established principles of physical optics.

The observations and experiments mentioned in my first paper (of 1873) establish the fact that, in so far as aperture is *effective* in microscopical vision, we have nothing like shadow effects or other indications of *solidity* in the image. The advantage of oblique illumination is shown to be *solely* based on the fact that with an oblique incident beam, diffraction beams can be taken-in by the objective which are lost for the same aperture with a direct pencil. It has been ascertained by various experiments that the peculiar effects which arise from oblique illumination are *always* manifested, even if the objects, from their well-known structure, cannot possibly admit of shadow or similar effects. Moreover, it has been directly shown that the benefit of this kind of illumination by no means depends on obliquity *quâ* obliquity. For if it were so it would necessarily involve the consequence that the same benefit must be obtained by means of a direct pencil if the preparation were *inclined* to the axis of the Microscope. The fact, however, is, that when we have a structure (of any kind whatever) which is *not* depicted in the ordinary position with direct light by an objective of given aperture-angle, say 40°, it is *never* depicted by that objective when the object is inclined at any angle, *even if it is depicted in the former position by another objective of slightly increased aperture only.*

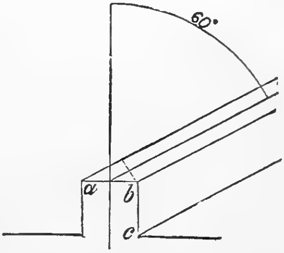
Apart from all experiment, the first principles of undulatory optics lead to the same inference. The laws of rectilinear propagation of the luminous rays, of reflection and refraction, are not *absolute* laws. They arise from and depend on a certain *relation* between the wave-lengths and the *absolute* dimensions of the objects by which the luminous waves are intercepted, or reflected, or refracted. They do not hold good unless these objects represent *large* multiples of the wave-length. With minute elements, measuring a fraction of λ, or a few wave-lengths only, we have nothing like shadows or similar effects of solidity (and nothing like prismatic or lenticular refractions), for the same reason that we have no perceptible *acoustic* shadow behind the trunk of a tree, except for notes of a very high pitch. Luminous as well as sonorous waves go all round obstacles whose dimensions are not large multiples of their own length.

The suggestion of a peculiar efficiency of obliquity in microscopical vision, taken from the analogy of oblique vision and oblique illumination in ordinary visual observation, is thus devoid of any sound basis.

Regarding the other suggestion, illustrated by the analogy of the 100 eyes around the object, this also has some very weak points. Particularly, it overlooks one little difference. Suppose these 100 eyes to be simultaneously used, and to receive on their retinas the 100 different aspects of the object; and suppose, now, all these various images *collected upon the same retina*—as is done in the Microscope; then you will conceive *what* would be the benefit of such all-round or solid vision. In the same degree as there would be a real difference among the various images, in the same degree the *total* image would become more and more confused, and would at all events show less than any *one* of the partial images could have exhibited. The single fact that we obtain distinct and well-defined vision by means of wide apertures, and that for the observation of very minute structures such wide apertures are required, at once disproves the notion that their effects depend on such circumstances as solid vision with the naked eye or with the binocular Microscope. Whenever we have the advantage of solid vision, owing to a different perspective projection of different images, in the Microscope or otherwise, this is solely because these different images are seen by *different* eyes.

There is, however, still another point of view under which the essential difference between wide-angle vision in the Microscope and variety of perspectives in ordinary vision becomes very evident. Suppose for a moment that there *did* exist a different perspective of a microscopical image by axial and by oblique rays, *similar to that in ordinary vision;* and suppose a minute cubical prominence *a b c* (Fig. 3) on an object to be observed by a wide-angled objective allowing an obliquity up to 60°. If it were true that the oblique beams project both faces *a b* and *b c* of the cube, whilst direct beams depict *a b* only, it must certainly be just as true that the face *a b* must be seen *shortened* by the oblique rays in the proportion of 1 : 2, as it of course is in ordinary vision. But what is true for the small facets of a minute ridge must also be true for any larger portion of the field. Under the above assumption, any larger object, as a *Pleurosigma* scale, ought to appear shortened, and the markings *closer* together by 1 : 2, in the direction of incidence of a pencil of 60° obliquity; or, in other terms, the objective ought to yield only *half its amplification* in that direction.

Fig. 3.



No microscopist has ever yet observed such a thing; and if it did exist, microscopical vision even with very moderate apertures would be entirely destroyed. In point of fact, the *identity* of power or amplification with *all* obliquities embraced by the aperture-angle is the essential criterion of an *aplanatic* system; and the law of convergence of the rays at conjugate aplanatic foci which was applied for the determination of the aperture-equivalent, is, as has been deduced by the author, the necessary and sufficient condition of *identical amplification* in wide-angled systems, without which no image could be delineated by such systems.

This consideration shows that the diverse obliquities of the rays in a wide-angled system cannot give rise to anything like all-round vision, because in the Microscope there is no difference of *projection* connected with different obliquities.

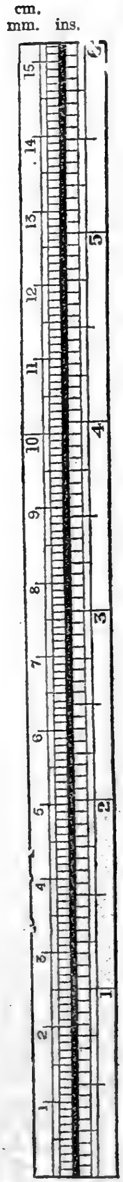
In the binocular Microscope we have, as a matter of fact, a diversity of images which are depicted by pencils of different obliquities at the object; and this, it is true, is a *certain kind* of perspective difference. As, however, the above observations show, even in this case the circumstances must be, in essential respects, different to those of ordinary vision. One important element of solid vision with the naked eye, the perspective *shortening* of lines and surfaces by oblique projection, is entirely lost in the Microscope; there remains only the other element, a relative displacement of consecutive planes in the image, which, of course, is still competent to afford sufficient indications for a stereoscopic coalescence of the impressions. But the fact that these displacements are seen in the Microscope depends upon a peculiar property of microscopic amplification, which by itself is a strong contrast to macroscopic vision; for this visibility depends entirely on the fact that the amplification of the depth is largely exaggerated—is always the *square* of the linear amplification in the other direction reduced in the proportion of the refractive index of the medium in which the object is.

Taking regard at the same time to the general inferences from undulatory optics, referred to above, it is seen that solid vision—i. e. delineation of objects *like* solid objects—is confined, even in the binocular Microscope, to relatively coarse elements, the dimensions of which are large multiples of the wave-length. Whenever elements *require*, for being delineated, the utilization of oblique rays, that is, of wide (and even moderate) apertures, the *arrangement* of such elements within a solid space of sufficient dimensions may be seen still with the characteristics of solid vision, but the elements *themselves* are no longer depicted as solid objects of larger dimensions would be depicted. A *Pleurosigma valve* may be seen as a solid object, by an unconscious stereoscopic impression in the binocular Microscope, or by a mental combination of the images of successive planes in the monocular; but the *corpuscules* which compose the valve can never be seen as solids, unless we could obtain objectives of a numerical aperture at least = 8 or 10, and could discover an imbedding substance of the same refractive index, in order to gain an image by means of rays of 8 or 10 times *shorter* wave-length.

The very first step of every understanding of the Microscope is to abandon the gratuitous assumption of our ancestors, that microscopical vision is an *imitation* of macroscopical, and to become familiar with the idea that it is a thing *sui generis*, in regard to which nothing can be legitimately inferred from the optical phenomena connected with bodies of large size.

I. Conversion of British and Metric Lineal Measures.

Scale of Inches, Centimetres, &c.



1000 μ = 1 mm.
10 mm. = 1 cm.
10 cm. = 1 dm.
10 dm. = 1 metre.

Inches, &c., into Micromillimetres, Millimetres, &c.

ins.	μ
$\frac{1}{25000}$	1·015991
$\frac{1}{20000}$	1·269989
$\frac{1}{15000}$	1·693318
$\frac{1}{10000}$	2·539977
$\frac{1}{9000}$	2·822197
$\frac{1}{8000}$	3·174971
$\frac{1}{7000}$	3·628539
$\frac{1}{6000}$	4·233295
$\frac{1}{5000}$	5·079954
$\frac{1}{4000}$	6·349943
$\frac{1}{3000}$	8·466591
$\frac{1}{2000}$	12·699886
$\frac{1}{1000}$	25·399772
	mm.
$\frac{1}{900}$	·028222
$\frac{1}{800}$	·031750
$\frac{1}{700}$	·036285
$\frac{1}{600}$	·042333
$\frac{1}{500}$	·050800
$\frac{1}{450}$	·056444
$\frac{1}{400}$	·063499
$\frac{1}{350}$	·072571
$\frac{1}{300}$	·084666
$\frac{1}{250}$	·101599
$\frac{1}{200}$	·126999
$\frac{1}{150}$	·169332
$\frac{1}{100}$	·253998
$\frac{1}{50}$	·507995
$\frac{1}{25}$	1·015991
$\frac{1}{20}$	1·269989
$\frac{1}{16}$	1·587486
$\frac{1}{15}$	1·693318
$\frac{1}{12}$	2·116648
$\frac{1}{10}$	2·539977
$\frac{1}{8}$	3·174971
$\frac{1}{6}$	4·233295
$\frac{3}{16}$	4·762457
$\frac{1}{5}$	5·079954
$\frac{1}{4}$	6·349943
$\frac{5}{16}$	7·937429
$\frac{3}{8}$	9·524914
$\frac{7}{16}$	11·112400
$\frac{1}{2}$	12·699886
$\frac{9}{16}$	14·287372
$\frac{5}{8}$	15·874857
$\frac{11}{16}$	17·462343
$\frac{3}{4}$	19·049829
$\frac{13}{16}$	20·637315
$\frac{7}{8}$	22·224800
$\frac{15}{16}$	23·812286
1	25·399772
2	50·799544
3	76·199316
4	101·599088
5	126·998860
6	152·398632
7	177·798404
8	203·198176
9	228·597948
10	253·997720
11	279·397492
1 ft.	304·797264
	metres.
=	·304797
1 yd. =	·914392

Micromillimetres, Millimetres, &c., into Inches, &c.

μ	ins.	mm.	ins.	mm.	ins.
1	·000039	1	·039370	51	2·007892
2	·000079	2	·078741	52	2·047262
3	·000118	3	·118111	53	2·086633
4	·000157	4	·157482	54	2·126003
5	·000197	5	·196852	55	2·165374
6	·000236	6	·236223	56	2·204744
7	·000276	7	·275593	57	2·244115
8	·000315	8	·314963	58	2·283485
9	·000354	9	·354334	59	2·322855
10	·000394	10 (1 cm.)	·393704	60 (6 cm.)	2·362226
11	·000433	11	·433075	61	2·401596
12	·000472	12	·472445	62	2·440967
13	·000512	13	·511816	63	2·480337
14	·000551	14	·551186	64	2·519708
15	·000591	15	·590556	65	2·559078
16	·000630	16	·629927	66	2·598448
17	·000669	17	·669297	67	2·637819
18	·000709	18	·708668	68	2·677189
19	·000748	19	·748038	69	2·716560
20	·000787	20 (2 cm.)	·787409	70 (7 cm.)	2·755930
21	·000827	21	·826779	71	2·795301
22	·000866	22	·866149	72	2·834671
23	·000906	23	·905520	73	2·874041
24	·000945	24	·944890	74	2·913412
25	·000984	25	·984261	75	2·952782
26	·001024	26	·023631	76	2·992153
27	·001063	27	1·063002	77	3·031523
28	·001102	28	1·102372	78	3·070894
29	·001142	29	1·141742	79	3·110264
30	·001181	30 (3 cm.)	1·181113	80 (8 cm.)	3·149634
31	·001220	31	1·220483	81	3·189005
32	·001260	32	1·259854	82	3·228375
33	·001299	33	1·299224	83	3·267746
34	·001339	34	1·338595	84	3·307116
35	·001378	35	1·377965	85	3·346487
36	·001417	36	1·417335	86	3·385857
37	·001457	37	1·456706	87	3·425227
38	·001496	38	1·496076	88	3·464598
39	·001535	39	1·535447	89	3·503968
40	·001575	40 (4 cm.)	1·574817	90 (9 cm.)	3·543339
41	·001614	41	1·614188	91	3·582709
42	·001654	42	1·653558	92	3·622080
43	·001693	43	1·692928	93	3·661450
44	·001732	44	1·732299	94	3·700820
45	·001772	45	1·771669	95	3·740191
46	·001811	46	1·811040	96	3·779561
47	·001850	47	1·850410	97	3·818932
48	·001890	48	1·889781	98	3·858302
49	·001929	49	1·929151	99	3·897673
50	·001969	50 (5 cm.)	1·968521	100 (10 cm. = 1 decim.)	
60	·002362				
70	·002756				
80	·003150				
90	·003543				
100	·003937				
200	·007874				
300	·011811				
400	·015748				
500	·019685				
600	·023622				
700	·027559				
800	·031496				
900	·035433				
1000 (= 1 mm.)					

decim.	ins.
1	3·937043
2	7·874086
3	11·811129
4	15·748172
5	19·685215
6	23·622258
7	27·559301
8	31·496344
9	35·433387
10 (1 metre)	39·370430
	= 3·280869 ft.
	= 1·093623 yds.

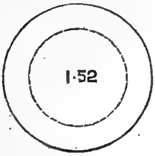
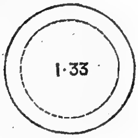
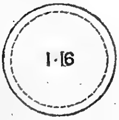
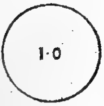
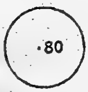
II. NUMERICAL APERTURE TABLE.

The "APERTURE" of an optical instrument indicates its greater or less capacity for receiving rays from the object and transmitting them to the image.

In the *Telescope*-objective its aperture is determined by the diameter of the admitted pencil at its entrance—that is, the *absolute* (utilized) diameter of the objective.

In the *Microscope*-objective its aperture is determined by the ratio between the focal length and the diameter of the emergent pencil at the plane of its emergence—that is, the *relative* diameter of the single-lens objective or of the back lens of a compound objective.

This ratio is expressed for all media and all cases by $n \sin u$, n being the refractive index of the medium and u the semi-angle of aperture. The values of $n \sin u$ for any particular cases are the "*numerical apertures*" of the objectives.

Diameters of the Back Lenses of various Dry and Immersion Objectives of the same Power (¼ in.) from 0·50 to 1·52 N. A.	**Numerical Aperture.** ($n \sin u = a$.)	Angles of Aperture ($= 2u$).			Illuminating Power. (a^2.)	Theoretical Resolving Power, in Lines to an Inch. ($\lambda = 0{\cdot}5269\,\mu$ =line E.)
		Dry Objectives. ($n = 1$.)	*Water-Immersion* Objectives. ($n = 1{\cdot}33$.)	*Homogeneous Immersion* Objectives. ($n = 1{\cdot}52$.)		
	**1·52**	..	..	180° 0′	2·31	146,528
	1·50	..	..	161° 23′	2·25	144,600
	1·48	..	..	153° 39′	2·19	142,672
	1·46	..	..	147° 42′	2·13	140,744
	1·44	..	..	142° 40′	2·07	138,816
	1·42	..	..	138° 12′	2·02	136,888
	1·40	..	..	134° 10′	1·96	134,960
	1·38	..	..	130° 26′	1·90	133,032
	1·36	..	..	126° 57′	1·85	131,104
	1·34	..	..	123° 40′	1·80	129,176
	**1·33**	..	180° 0′	122° 6′	1·77	128,212
	1·32	..	165° 56′	120° 33′	1·74	127,248
	1·30	..	155° 38′	117° 34′	1·69	125,320
	1·28	..	148° 28′	114° 44′	1·64	123,392
	1·26	..	142° 39′	111° 59′	1·59	121,464
	1·24	..	137° 36′	109° 20′	1·54	119,536
	1·22	..	133° 4′	106° 45′	1·49	117,608
	1·20	..	128° 55′	104° 15′	1·44	115,680
	1·18	..	125° 3′	101° 50′	1·39	113,752
	**1·16**	..	121° 26′	99° 29′	1·35	111,824
	1·14	..	118° 00′	97° 11′	1·30	109,896
	1·12	..	114° 44′	94° 56′	1·25	107,968
	1·10	..	111° 36′	92° 43′	1·21	106,040
	1·08	..	108° 36′	90° 33′	1·17	104,112
	1·06	..	105° 42′	88° 26′	1·12	102,184
	1·04	..	102° 53′	86° 21′	1·08	100,256
	1·02	..	100° 10′	84° 18′	1·04	98,328
	**1·0**	180° 0′	97° 31′	82° 17′	1·00	96,400
	0·98	157° 2′	94° 56′	80° 17′	·96	94,472
	0·96	147° 29′	92° 24′	78° 20′	·92	92,544
	0·94	140° 6′	89° 56′	76° 24′	·88	90,616
	0·92	133° 51′	87° 32′	74° 30′	·85	88,688
	**0·90**	128° 19′	85° 10′	72° 36′	·81	86,760
	0·88	123° 17′	82° 51′	70° 44′	·77	84,832
	0·86	118° 38′	80° 34′	68° 54′	·74	82,904
	0·84	114° 17′	78° 20′	67° 6′	·71	80,976
	0·82	110° 10′	76° 8′	65° 18′	·67	79,048
	**0·80**	106° 16′	73° 58′	63° 31′	·64	77,120
	0·78	102° 31′	71° 49′	61° 45′	·61	75,192
	0·76	98° 56′	69° 42′	60° 0′	·58	73,264
	0·74	95° 28′	67° 36′	58° 16′	·55	71,336
	0·72	92° 6′	65° 32′	56° 32′	·52	69,408
	**0·70**	88° 51′	63° 31′	54° 50′	·49	67,480
	0·68	85° 41′	61° 30′	53° 9′	·46	65,552
	0·66	82° 36′	59° 30′	51° 28′	·44	63,624
	0·64	79° 35′	57° 31′	49° 48′	·41	61,696
	0·62	76° 38′	55° 34′	48° 9′	·38	59,768
	**0·60**	73° 44′	53° 38′	46° 30′	·36	57,840
	0·58	70° 54′	51° 42′	44° 51′	·34	55,912
	0·56	68° 6′	49° 48′	43° 14′	·31	53,984
	0·54	65° 22′	47° 54′	41° 37′	·29	52,056
	0·52	62° 40′	46° 2′	40° 0′	·27	50,128
	**0·50**	60° 0′	44° 10′	38° 24′	·25	48,200

THE
ROYAL MICROSCOPICAL SOCIETY.

(Founded in 1839. Incorporated by Royal Charter in 1866.)

The Society was established for the communication and discussion of observations and discoveries (1) tending to improvements in the construction and mode of application of the Microscope, or (2) relating to Biological or other subjects of Microscopical Research.

It consists of Ordinary, Honorary, and Ex-officio Fellows.

Ordinary Fellows are elected on a Certificate of Recommendation signed by three Fellows, stating the names, residence, description, &c., of the Candidate, of whom one of the proposers must have personal knowledge. The Certificate is read at a Monthly Meeting, and the Candidate balloted for at the succeeding Meeting.

The Annual Subscription is 2*l.* 2*s.*, payable in advance on election, and subsequently on 1st January annually, with an Entrance Fee of 2*l.* 2*s.* Future payments of the former may be compounded for at any time for 31*l.* 10*s.* Fellows elected at a meeting subsequent to that in June are only called upon for one-half of the year's subscription, and Fellows absent from the United Kingdom for a year, or permanently residing abroad, are exempt from one-half the subscription during absence.

Honorary Fellows (limited to 50), consisting of persons eminent in Microscopical or Biological Science, are elected on the recommendation of three Fellows and the approval of the Council.

Ex-officio Fellows (limited to 100) consist of the Presidents for the time being of such Societies at home and abroad as the Council may recommend and a Monthly Meeting approve. They are entitled to receive the Society's Publications, and to exercise all other privileges of Fellows, except voting, but are not required to pay any Entrance Fee or Annual Subscription.

The Council, in whom the management of the affairs of the Society is vested, is elected annually, and is composed of the President, four Vice-Presidents, Treasurer, two Secretaries, and twelve other Fellows.

The Meetings are held on the second Wednesday in each month, from October to June, in the Society's Library at King's College, Strand, W.C. (commencing at 8 P.M.). Visitors are admitted by the introduction of Fellows.

In each Session two additional evenings are devoted to the exhibition of Instruments, Apparatus, and Objects of novelty or interest relating to the Microscope or the subjects of Microscopical Research.

The Journal, containing the Transactions and Proceedings of the Society, with a Summary of Current Researches relating to Zoology and Botany (principally Invertebrata and Cryptogamia), Microscopy, &c., is published bi-monthly, and is forwarded *gratis* to all Ordinary and Ex-officio Fellows residing in countries within the Postal Union.

The Library, with the Instruments, Apparatus, and Cabinet of Objects, is open for the use of Fellows on Mondays, Tuesdays, Thursdays, and Fridays, from 11 A.M. to 4 P.M., and on Wednesdays from 7 to 10 P.M. It is closed during August.

Forms of proposal for Fellowship, and any further information, may be obtained by application to the Secretaries, or Assistant-Secretary, at the Library of the Society, King's College, Strand, W.C.