XXII. *The Reproduction of the* Ascaris mystax. *By* Henry Nelson, *M.D.* *Communicated by* Allen Thomson, *M.D., F.R.S., Professor of Anatomy in the University of Glasgow.*

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Having been led to investigate the mode of generation and development of the *Ascaris mystax*, I venture to lay before the Royal Society the results of my observations, in the hope that they may not be devoid of interest.

The worm in question has been long known to helminthologists (Plate XXV*. figs. 3 and 4); it varies from 1 to 3 inches in length, is fusiform, and covered with a striated horny cuticle, which is projected on either side of the head to form the alæ characteristic of the species (fig. 1 *a*).

The *Ascaris mystax* is found within the intestinal canal of the domestic Cat. So common is it, that out of about thirty examined for the purpose I have not failed to find them in more than three or four cases.

The part in which they are generally found in the greatest abundance is that portion of the duodenum between the pylorus and the opening of the bile-duct. When the cat has fasted for some hours, the Ascarides pass the pyloric valve into the stomach, apparently in search of food; but this is never the case during digestion; on the contrary, they appear to be then swept further down the intestinal canal than the part they normally occupy.

The male *Ascaris mystax* (fig. 3) is about an inch and a quarter in length; while the female (fig. 4) is from 2 to 3 inches, and occasionally even 4 inches.

The males are easily distinguishable by their size and the peculiar curve of their tails (fig. 3 *a*), which are coiled round on the ventral aspect, while those of the females increase slightly in thickness to within a short distance of their termination, and are perfectly straight without any curvature of the point (fig. 4 *a*).

This creature derives its specific name from two lateral projections on either side of the head resembling moustaches (fig. 1 *a*). These projections or alæ are flat, transparent and striated, being covered by the horny cuticle which envelopes the whole body (fig. 1 *d*). In front is the mouth with its three lobes (fig. 1 *b*) opening directly into the intestinal canal (fig. 1 *c*). The entire body is covered with cartilaginous rings placed side by side and exactly of the same breadth, the whole forming one continuous cuticular envelope, appearing to be regularly striated when viewed externally (fig. 1 *d*).

The posterior extremity of the female becomes suddenly narrowed to a blunt point (fig. 4 *a*), a short distance from which is the anal aperture.

The tail of the male, as I have said, is abruptly curved on itself (fig. 3 *a*), so that its dorsum is convex (fig. 5 *a*) and its ventral aspect concave (fig. 5 *b*). A short distance from the conical apex and on the ventral surface (fig. 2 *b*) is the anus (figs. 2 and 5 *c*), and a little in front of this is the genital orifice (figs. 2 and 5 *d*).

On either side of the concave surface (fig. 2 *b*) in the male is a projecting ridge (fig. 2 *f*), consisting of a number of conical tubercles placed in a row and supporting a horny membrane that stretches between them. This membrane is finely serrated; the teeth look towards the tail, and no doubt serve an important part in giving it a secure hold while embracing the body of the female.

The intestinal canal is a straight tube (figs. 1 *c* and 5 *i*) passing from the mouth to the anus, situated in the axis of the body and surrounded by loose cellular tissue. It usually contains undigested particles and portions of intestinal villi of the Cat.

After this general description, I pass to the consideration of the reproductive organs, and commence with the generative apparatus of the male as being the more simple.

By squeezing the tail carefully between plates of glass two spicula (fig. 2 *g*) are forced out of the genital orifice (fig. 2 *d*), already mentioned. These spicula are slightly curved, the curvature looking towards the body, and in the ordinary state of the parts are entirely retracted within the trunk. They are placed one before the other, they are about $\frac{1}{20}$th of an inch in length and $\frac{1}{1600}$dth in breadth; their consistence is horny, their structure tubular with a joint at the base (fig. 6 *f*), which allows of the spiculum being withdrawn (fig. 5 *g*). That part beyond the joint (fig. 6 *c*, *f*) which always remains within the body even when the spiculum is protruded, is cartilaginous in appearance, and is furnished with tooth-like projections for the attachment of the muscles engaged in its protrusion and retraction, fig. 6 *d*. Near the apex is an aperture (fig. 7 *b*) by which the seminal fluid escapes, when forced along the tubular spiculum (figs. 6 and 7 *a*).

Of the way in which copulation takes place I can speak with certainty, having in my possession a specimen in which the tail of the male is wound round so as to embrace that portion of the trunk of the female where the orifice of the vagina (Plate XXX. fig. 91 *a*) is situated, by which means the spicula are directed into its cavity.

The internal organs of generation in the male consist of a single tube variously contracted and dilated, but without any branching or division (Plate XXV*. fig. 5 *h*, *k*, *m*, *n*, *o*). This tube is placed between the integument and the intestinal canal (fig. 5 *i*) and originates in a very fine cæcal extremity (fig. 5 *o*). As it gradually enlarges it becomes much contorted, doubled backwards and forwards, surrounding the intestinal canal and occupying the posterior half of the body.

Commencing at the narrow extremity (fig. 5 *o*) is a very long tubular portion (fig. 5 *o*, *m*) that answers to the testicle; joined to this is the seminal vesicle (fig. 5 *k*),

which is dilated, and several times the diameter of the testicular tube. Lastly, the seminal vesicle contracts slightly and forms the sheath of the spicula (fig. 5 *h*). The membrane forming the cæcal extremity (fig. 8 *a*) is very thick but soon becomes thin, so that the upper portion of the testicle (fig. 5 *o*) is perfectly transparent, and at the same time homogeneous (fig. 8 *b*). On examining the membranous walls of the generative tube lower down, they first present a granular appearance (fig. 9 *b*), and then longitudinal striæ along with the finely granular structure (fig. 10 *b*). A little above the seminal vesicle (fig. 5 *k*) the tube becomes muscular, presenting transverse rugæ (fig. 11), intended no doubt to force forward the contents. This muscular portion, which may be called the vas deferens (fig. 5 *m*), connects the testicle (fig. 5 *o*, *n*) with the seminal vesicle (fig. 5 *k*), and from its contractility remains constantly empty and therefore transparent. The vesicle itself (fig. 5 *k*) is covered by reticulations of long muscular fibrillæ, giving it the appearance of being enclosed in a net. When these fibres contract, the contained semen must be expelled with considerable power. The spicula also are provided with special muscles for protrusion and retraction, but into the particulars of these I shall not enter, passing to the far more important investigation of the mode in which the seminal particles are developed.

I have already described the apex of the cæcal extremity (fig. 8 *a*) as composed of a very thick membrane, but this membrane, although perfectly well defined on the exterior is not so within. Externally homogeneous, it becomes internally more and more granular till its inner surface appears almost entirely composed of very minute granules (fig. 8 *c*).

This is the true secreting organ, for the granules when thrown off begin immediately to swell and form nucleated cells (figs. 8 and 9 *d*). The homogeneous portion of the testicle is filled with little else than these cells of various sizes, floating in a transparent fluid (fig. 8), but as it becomes gradually striated, the cells are obscured by an immense number of minute opake granules (fig. 9 *a*).

The nucleated cells (fig. 9 *d*) and granules (fig. 9 *a*) are at first intermixed without any order, but further down the granules group themselves round the cells (fig. 9 *f*), forming envelopes for each individually (fig. 10 *a*). On rupturing the testicular tube at its commencement, the nucleated cells (Plate XXVI. fig. 18 *a*) are protruded, floating in a granular fluid (fig. 18 *b*); they have a very transparent cell-wall and a nucleus attached to one side (fig. 18 *d*). About the middle we find the granular masses (fig. 19 *a*) irregular in form, but within which the nucleated spermatic cells (fig. 19 *b*) may be distinctly seen. The masses are however so delicate that the slightest pressure destroys them altogether (fig. 19 *c*). Passing as far down as the muscular portion of the testicular tube, the vas deferens (Plate XXV*. fig. 5 *m*), we find the masses much smaller in size as well as more regular in shape (Plate XXVI. fig. 20 *a*). The granular envelope is globular with a well-defined margin and perfectly opake, so as to render invisible the included cell except when ruptured by

pressure (fig. 20 *b*). This (fig. 20 *a*) is the utmost development the semen undergoes, as long as it remains in the male organs. These granular envelopes (fig. 20 *a*) appear to perform the important function of preserving and preventing the enlargement of the spermatic cells contained within them (fig. 20 *c*), for sometimes, but very rarely, a spermatic cell may be seen, which having escaped from its granular covering, has swollen up to three times its former size (fig. 20 *d*), an occurrence which, if it happened more frequently, would prevent their passage through the spiculæ, whose calibre is only capable of admitting a single granular mass at a time.

Although the further changes which the spermatic cells undergo take place within the female, and consequently totally unconnected with the generative apparatus of the male, for the sake of continuity and to prevent confusion, I shall treat of them here.

On examining the uterine contents of a recently impregnated *Ascaris mystax*, a granular fluid is observed in which a number of nucleated cells are floating, but I have never been able to observe the granular masses already described as seen in the male. The disappearance then of the granular envelope (fig. 20 *a*, *b*) is the first visible change in the constitution of the semen, and can be accounted for in many ways.

The loose granules are the debris of the cell cases; while the nucleated cells (Plate XXVI. figs. 21–36) are simply the spermatic cells (fig. 20 *c*) much enlarged, apparently by the spontaneous imbibition of the surrounding fluid. By this enlargement, a most beautifully transparent spherical cell (figs. 21, 22 *a*) is produced $\frac{1}{900}$th of an inch in diameter, enclosing, or rather having attached to its inner surface a round, discoidal nucleus (fig. 21 *b*), and within this a nucleolus (fig. 21 c), sometimes even two nucleoli.

Before I describe, however, the transformation of these nuclei into spermatic particles, it will be useful to examine cursorily the statements of others on the subject.

Wagner and Leuckardt, in their article on Semen, in Todd's Cyclopædia, speaking of the *Ascaris acuminata*, say, "the nucleus has at first a roundish shape (fig. 12 *a*), but gradually stretches itself more and more, and projects more or less outwards with its point (figs. 13, 14, 15 *a*); thus metamorphosing itself into the peduncle-like appendix of the spermatozoon, the body of which is formed from the persisting membrane of the seminal cell"(figs. 12 to 15 *b*).

Kolliker states that these cells (fig. 16 *a*) are formed four at a time within other larger cells (fig. 16 *b*); and that the elongated nuclei of Siebold and Wagner (figs. 14, 15 *a*) are mere bundles of undeveloped spermatozoa, whose form he supposes, but has never seen, to be capillary.

Reichert, in his researches on the development of the spermatozoa of the *Ascaris acuminata*, indicates a spermatic cell containing a nucleus and nucleolus (fig. 17). The cell increases in size (fig. 17 *a*), as does the nucleolus (fig. 17 *c*); but the nucleus becomes less definite, and retains its former size (fig. 17 *b*).

This, then, according to him, is the fully-formed spermatozoon, consisting of a spherical cell (fig. 17 *a*), a nucleolus (fig. 17 *c*), and indistinct nucleus (fig. 17 *b*).

This is the substance of previous investigations respecting the development of the spermatic particles. I now proceed to state my observations as to their formation in the *Ascaris mystax*, the phenomena of which will be found to differ materially from those just described.

I have previously stated, that in the more developed condition of the spermatic cells they appear as transparent vesicles, without any granular envelope (figs. 21, 22 *a*), but containing a nucleus (figs. 21, 22 *b*) and nucleolus (figs. 21, 22 *c*). The nucleus appears discoidal when seen from above (fig. 21 *b*), but lenticular when viewed in profile (fig. 22 *b*), apparently enclosed between two portions of the membranous cell-wall (figs. 22 *a* and *d*). The internal margin of the nucleus (fig. 22 *d*) soon loses its clear and defined outline (fig. 23 *b*); the granular mass constituting the nucleus undergoes a marked increase in volume, projecting in a more or less conical form towards the centre of the cell (figs. 23–28 *b*). A membrane is then formed over the whole of that part of the nucleus which is in contact with the wall of the spermatic cell (figs. 23, 24, *f*). This membrane is very distinctly seen to separate the granular matter of the nucleus from the external cell, with which it is in accurate contact. It is also an entirely new formation not to be found in any of the former stages, and is apparently produced at the expense of the most external granules of the nucleus. The margin, however, of this discoidal membrane (figs. 23, 28 *f*) is not in apposition with the cell-wall, but has a tendency to surround and enclose the nucleus; giving the membrane the form of a watch-glass, whose convexity is in contact with the spermatic cell, while in its concavity are contained the granules of the nucleus, of which it forms a part. The watch-glass form, however, is soon lost, the membrane acquiring a tendency to become more convex at its centre, assumes first the appearance of a cup, filled to overflowing with the granular substance (fig. 31 *f*), then that of a rounded cone whose margin is everted or bell-shaped (fig. 32 *f*); though this is sometimes not to be seen from the nuclear matter which surrounds and hides it from view (fig. 33 *f*).

When this convexity takes place exactly in the middle, the external cell-wall is projected in the form of a papilla (figs. 24 to 27 *a*), but this is probably only an accidental occurrence, and not the general rule.

Although at variance with the statements of WAGNER, I say this with the more confidence, as DR. ALLEN THOMSON, with whom I had an opportunity of examining these changes, most fully coincides in the view I have here taken. A slight projection of the external cell-wall is indeed common at one period; but in no instance have I observed a greater amount of protrusion than that figured in (fig. 27 *a*). The elongation of the nucleus into a tail must be regarded as doubtful in the *Ascaris acuminata*, as it is certainly not the case in the *Ascaris mystax*.

How then is the spermatic particle formed? I have described the tendency of the nuclear membrane to become more and more convex; as this convexity increases the apex impinges more or less obliquely against the cell-wall (figs. 28, 32, 33 *a*), protruding it slightly at the same time that it is itself diverted from the straight course, becoming bent into a curved form (figs. 29, 30 *f*). By this time the granular portion of the nucleus has become much diminished in volume, still presenting, however, the nucleolus (fig. 34 *c*); while the nuclear membrane has passed from the conical to a cylindrical shape (fig. 34 *f*). During these changes in form, the nuclear membrane likewise increases in thickness, and presents a double outline (figs. 29 to 34 *f*), and refracts light strongly.

By contraction in its transverse diameter and elongation in the other, it gradually assumes the form of a test-tube (figs. 35, 36 *f*), bent, however, to adapt itself to the concavity of the spermatic cell (figs. 35, 36 *a*), often making a curve of a quarter of a circle.

From the period at which a double outline is first visible, the granules begin to disappear (figs. 29, 30 *b*), till at last the nucleus (fig. 22 *b*) becomes entirely transformed into an elongated cæcal tube (figs. 35, 36 *f*) with very thick sides, the cavity being occupied by a dark homogeneous substance, while at its mouth is found the nucleolus (figs. 35, 36 *c*) and a few granules that have not yet disappeared (figs. 35, 36 *b*); the whole, however, still enclosed within the spherical spermatic cell (figs. 35, 36 *a*).

The blind extremity next enlarges slightly, while the enveloping cell dissolves, and a flask-shaped body, the true spermatic particle, is thus set free (fig. 38).

Although the disappearance of the spermatic cell occurs normally at this period, it often happens much sooner, and thus we find the spermatic particles set free in all stages of their development, from the primitive nucleus (fig. 37 *b*) to the perfect condition (fig. 38).

In many of these spermatic particles the nucleolus (figs. 37, 38 *c*) still remains; but it also in course of time disappears, leaving the mouths of these hollow bodies apparently open (fig. 38 *g*).

Originally the nucleated cells (fig. 18 *a*) in the cæcal extremity of the testicle (fig. 8) are not more than $\frac{1}{10000}$th of an inch in diameter; as they descend they become enveloped by granules, at first forming irregular masses about $\frac{1}{1000}$th of an inch (fig. 19), but by gradual consolidation become the round, opake bodies which I have called granular masses (fig. 20 *a*), measuring $\frac{1}{1700}$th of an inch in diameter, and containing each a single spermatic cell, now, however, increased to $\frac{1}{2500}$th of an inch (fig. 20 *c*).

After the spermatic cells are introduced into the female uterus they enlarge rapidly, and are met with measuring from $\frac{1}{1000}$th to $\frac{1}{700}$th of an inch (figs. 21 to 36). The nucleus is about one third the diameter of the cell, or about $\frac{1}{2700}$th

of an inch (figs. 21 to 26 *b*); while the breadth of the spermatic particles varies from $\frac{1}{5000}$th to $\frac{1}{3600}$th of an inch, and their length from $\frac{1}{1600}$th to $\frac{1}{700}$th of an inch (figs. 37, 38 *f*, *g*).

The spermatic particles (figs 37, 38) have long been known, but their nature has not hitherto been fully determined.

CLOQUET, in his elaborate work on the *Ascaris lumbricoides*, mistook them for undeveloped ova. More lately, KOLLIKER imagined them to be bundles of capillary spermatic filaments.

WAGNER believes them to form the tail only of the spermatozoon (figs. 14, 15 *a*); while REICHERT evidently did not recognise their function, as he makes a nucleated cell (fig. 17) his "Reifes Saamen Körperchen."

Lastly, SIEBOLD conjectures these corpuscles to be spermatozoa, having seen them in contact with the ova, but appears to have gone no further into the investigation.

That these flask-shaped bodies (fig. 38) are the mature spermatic particles cannot now be doubted, as we meet with them the highest in the oviduct of the female, while near the external orifice of the vagina none but nucleated cells, or cup-shaped nuclei only are seen.

As already stated, I have never observed a spermatic particle forcing out the cell-wall, except at a very early period of its development (figs. 24 to 29); but when perfectly formed, it is set free by the total disappearance of the spermatic cell. Nothing then remains except a few granules surrounding the nucleolus (fig. 38 *b*, *c*); and, although the cell-wall is very frequently lost much earlier, the development of the nuclear membrane, which constitutes the spermatic particle, seems to go on as long as any granules remain to be transformed. WAGNER, therefore, is not correct in supposing these bodies to be mere tails, because they never project as such from the spermatic cells; also, when they become free, it is by the total disappearance of the cell; and lastly, because they alone are found highest in the oviduct.

Again, speaking relatively, what immense spermatozoa these cells (figs. 21 to 36) would make, if the opinions of WAGNER and REICHERT were correct, from $\frac{1}{1000}$th to $\frac{1}{700}$th of an inch in diameter, or one third that of the ovum in the same animal! a circumstance altogether unparalleled.

Neither do I see any reason to believe KOLLIKER's statement, that the spermatic cells are formed four at a time, within a mother-cell (fig. 16), never having observed such an occurrence.

The whole of the changes I have described may easily be traced by examining the uteri of the larger individuals, as in these impregnation has in all probability not occurred till very lately; their size apparently depending on the non-evolution of fertile ova.

However, from the delicacy and transparent nature of the spermatic cell, when at its greatest development, the very best microscopes must be employed in order to detect it.

Having now fully traced the formation of the spermatic particles, from the nucleated granule, thrown off by the cæcal extremity of the testicular tube (Plate XXV*. fig. 8 *d*) to the flask-shaped body met with in the oviduct (Plate XXVI. fig. 38), I now pass to the description of the female organism, previous to entering on the development of the ovum.

The female *Ascaris*, as I have already said (Plate XXV*. fig. 4), is larger than the male (fig. 3); its tail also is straight (fig. 4 *a*) and not curled up (fig. 3 *a*).

The orifice of the vagina (Plate XXX. fig. 91 *a*) is placed about one third the length of the animal from the head; it is a simple circular opening, but so small as to be seen with the greatest difficulty. The ovarian tubes, on the other hand, may be seen filling the body with convolutions, reaching from the tail to within a short distance of the head.

The reproductive apparatus is not firmly fixed in one position, but moves backwards and forwards with considerable facility in the space between the intestinal tube and integument.

The following is the method I employed for the extraction of these generative tubes. Cut off the head and neck a little above the convolutions, and seizing the tail with forceps, by very gradually increased pressure, commencing at the tail and passed along the body towards the cut extremity, squeeze out the whole visceral contents, leaving nothing but skin behind.

To prevent entanglement of the different parts it is best to effect this expression under water. When it has been accomplished, with needles unravel the convolutions and remove the intestinal canal, which is easily recognised by its straightness and great relative diameter. If carefully performed, we obtain two very long, almost capillary tubes (fig. 92 *a*, *b*, *c*, *d*), which after enlarging (fig. 92 *f*) become united into one canal (fig. 92 *g*), whose termination has already been described as the generative orifice (fig. 91 *a*).

On examining the reproductive apparatus (fig. 92) we observe it to be composed of several portions, differing in appearance as well as structure.

These tubes commence near the tail in two extremely delicate cæcal ends (fig. 92 *a*), gradually increase in size as well as in opacity, and after performing various convolutions backwards and forwards throughout the greater part of the body (fig. 92 *b*) they suddenly become constricted (fig. 92 *c*). This opake portion is the ovary, or rather the ovarian tube, and is from 4 to 6 inches in length; it is followed by an almost transparent piece from a quarter to half an inch in length, with a constriction at either end, separating it from the ovary on the one side and the part that immediately succeeds on the other (fig. 92 *c*, *d*). Each tube now becomes greatly dilated, so as to be several times the diameter of the former portions, forming what are termed the uteri (fig. 92 *f*).

The uteri are also half an inch long, lie parallel to each other, and unite together to form a vagina of about the same length (fig. 92 *g*). The opacity of the ovaries, uteri,

and vagina (fig. 92 *a*, *b*, *f*, *g*) is dependent on the eggs with which they are distended, while the transparent portion (fig. 92 *c*, *d*) contains hardly any (fig. 90 *c*, *d*).

This part has not received any definite name, nor have its limits been pointed out; but as it is here that the important process of fecundation takes place a name becomes indispensably necessary. To this, therefore, I shall apply the name of Oviduct (figs. 90 and 92 *c*, *d*).

The upper extremity of the ovary is formed of a membranous and perfectly transparent tube (Plate XXVII. fig. 39 *h*), much thicker at the very end (fig. 39 *a*). It is from this thick portion (fig. 39 *a*), which presents a finely granular structure, that the germinal vesicles are thrown off; it constitutes therefore the true ovary.

A short distance from the extremity, one or more apparent invaginations occur (fig. 39 *b*, *b*), as if other cæcal tubes were contained within the first; but these appearances are probably caused by casts of the internal surface of the upper end of the ovary (fig. 39 *a*), which are probably thrown off at intervals.

On examining a portion of the ovarian tube where it begins to be opake (fig. 40 *h*), we observe it marked with very faint lines and minute granules; but as we descend they gradually increase in distinctness. The sides also become thicker, so that about midway the tube is formed of a homogeneous membrane externally (fig. 41 *h*), continuous with that forming the cæcal extremity (fig. 39 *h*), and a number of longitudinal ridges or striæ internally (fig. 41 *l*). Each of these longitudinal striæ (fig. 41 *l*) contains a number of granules imbedded in them, causing them to project into the interior of the tube, and giving it somewhat the appearance of a rifle barrel (fig. 41 *k*).

This is the structure presented by the ovarian tube for the greater part of its length (fig. 41), commencing as soon as granules are seen to surround the germinal vesicles (fig. 40 *k*), and becoming gradually more distinct to within a short distance of the oviduct, where the striæ disappear and the external membrane alone remains (fig. 42 *h*).

The spot where the ovary terminates and the oviduct (fig. 42 *m*) begins is marked, as already stated, by a constriction (Plate XXX. fig. 90 *c*), causing such an amount of narrowing in the calibre of the generative tube (Plate XXVII. fig. 42 *m*) as only to admit the passage of one ovule at a time (fig. 42 *o*). The whole length of the oviduct (Plate XXX. fig. 90 *c*, *d*) is characterized by transverse markings, evidently of a muscular or contractile nature, and most developed at the ends where the constrictions (Plate XXVII. fig. 42 *m*) occur. While the exterior of the oviduct is transversely ribbed (fig. 42 *n*), its interior is lined with large cells, distended with a dark granular fluid, projecting into the cavity of the tube, and having all the appearance of secreting cells.

That these cells do secrete some sort of fluid, is proved by the fact that they become turgid when the *Ascaris* has been feeding, and are, on the contrary, almost invisible from flaccidity when it has had no food.

While the ovary is filled with an almost solid mass of ovules (Plate XXX. fig. 90 *b*),

the oviduct (fig. 90 *c, d*) contains a transparent, finely-granular fluid with only an ovule here and there. It is therefore probable that a peristaltic action being set up by the transverse muscular fibres of the oviduct, the ovules are detached and forced forwards singly into the uterus (fig. 90 *f*). Another constriction (fig. 90 *d*), but not so well marked as the first (fig. 90 *c*), indicates the termination of the oviduct, beyond which the tube becomes suddenly dilated into the uterus (fig. 90 *f*), which is several times the diameter of the preceding portions.

The uterus commences by a rounded extremity or fundus (fig. 90 *f*), into which the oviduct (fig. 90 *c, d*) opens, and gradually becomes narrower until it unites with its fellow (fig. 92 *f*) to form one tapering vagina (fig. 92 *g*). The uteri are formed of an external membrane (Plate XXVII. fig. 43 *h*) lined with broad, flat, quadrangular cells (fig. 43 *r*), each of which presents an oval or round nucleus (fig. 43 *s*) and a central nucleolus (fig. 43 *t*), of great beauty and distinctness.

Lastly, the vagina presents some transverse muscular rugæ externally, with nucleated flat cells internally, completing thus the complex structure of the female reproductive apparatus.

The cæcal extremity of the ovary (fig. 39 *a*) throws off, as I have said, small rounded granules (fig. 39 *c*), which enlarge rapidly and form the germinal vesicles (fig. 39 *d*).

These granules are formed by the thickened apex, and give its substance a semi-transparent structure (fig. 39 *a*). A fluid likewise fills the upper part of the ovarian tube, of an albuminous nature, and apparently the secretion of its walls. The germinal particles or granules when first thrown off, by the internal surface of the cæcal apex, are only $\frac{1}{10,000}$th of an inch in size (fig. 39 *c*), but begin almost immediately to increase to several times their original bulk, become vesicular (fig. 39 *d*), and present a nucleus within each cell (fig. 39 *f*). These are the germinal vesicles, and their included nuclei are the germinal spots (fig. 39 *d, f*).

Kolliker describes the invaginated appearance of the upper end of the ovary (fig. 39 *b*) as large cells whose nuclei are the germinal spots, which are set free by the successive openings of these large cells. (See Müller's Archiv for 1843.)

He further states that the germinal spot is first formed, and around it the germinal vesicle is developed like a primitive cell round its nucleus. My observations, however, lead me to believe that a germinal particle is first formed (fig. 39 *c*), which appears semiopake and solid (fig. 44 +); and that by the imbibition of the surrounding fluid the external membrane or layer of this germinal particle is distended, and thus forms the germinal vesicle (fig. 44 *b*), leaving the solid contents to form a central nucleus or germinal spot (fig. 44 *a*).

The germinal vesicles (fig. 39 *d*) are now $\frac{1}{3500}$th of an inch in size; as they pass down the ovary they disappear (fig. 40 *k*), becoming enveloped by opake granules (fig. 39 *g*).

At first, that is to say in the upper part of the ovarian tubes, these granules (fig. 39 *g*) are perfectly free, floating loosely in the fluid that surrounds them and lying in con-

tact, though not adherent to the germinal vesicles (figs. 39, 40 *d*). A little further down we observe the whole contents of the tubes to become gelatinous, and to consist apparently of nothing but granules. On applying gentle pressure so as to rupture this portion of the tube, the granular contents are easily forced out and may be seen to break up into semitransparent masses (figs. 45, 46).

Each mass (figs. 45, 46 *d*) constitutes an ovule, small and imperfect, but containing all the parts essential to an ovule. In the centre of each is a germinal vesicle (figs. 45, 46 *b*) enclosing a germinal spot (figs. 45, 46 *a*), and surrounded by opake granules (figs. 45, 46 *c*) imbedded in a transparent jelly-like substance.

These granules (figs. 45, 46 *c*) are of a fatty nature, and constitute the yolk in its primitive condition.

The ovule in this stage of its development is very irregular in form (figs. 45, 46), sometimes caudate, sometimes triangular, and at others round. They are all flattened and transparent, so that the contained germinal vesicle and spot may be distinctly recognised (figs. 45, 46 *a*, *b*) when viewed separately.

The distinctness of the outline which the transparent substance of the ovule presents (figs. 45, 46 *d*), led me at first to suppose that it was caused by a delicate enveloping membrane; but from further research I am led to believe that no such membrane exists, but that the distinct and regular outline is owing to the solidity and high refractive power of the clear substance (figs. 45, 46 *d*).

When the ovule is of a caudate or triangular form (fig. 45 *d*), the clear substance does not present so distinct an outline at the apex as elsewhere. From its being invariably placed nearest the centre of the ovarian tube it is probably the last formed, and therefore less consolidated than the other parts. It is doubtful whence the vitelline granules are formed (figs. 45, 46 *c*); they may be either thrown off by the cæcal extremity along with the germinal particles, separate spontaneously from the surrounding fluid, or be formed by the striated walls of the ovary.

I believe that the large granules (fig. 39 *g*), first seen to surround the germinal vesicles, are thrown off by the blind extremity, and become attached to them by the coagulation, or rather the consolidation of the surrounding albuminous fluid (figs. 45, 46). But when the ovule arrives at the striated portion (fig. 41) the number of yolk-granules is greatly increased (Plate XXVIII. figs. 48, 51 *c*), leading to the supposition that the granules contained within the striæ (Plate XXVII. fig. 41 *k*) are thrown off, and become imbedded in the clear substance of the ovule (Plate XXVIII. figs. 48, 51 *d*).

The possibility of such an occurrence cannot be doubted, both from the absence of a distinct limiting membrane round the ovule, as well as from the gelatinous nature of the clear substance, having a tendency to entangle and detain anything that may come in contact with it.

The germinal vesicles maintain exactly the same appearance, but increase a little in size (fig. 48 *b*), become globular in shape, and contain a highly refractive fluid

which makes them easily distinguishable. But while the germinal vesicle enlarges so slightly, the ovule increases rapidly as it descends the ovarian tube, passing from $\frac{1}{1000}$th to $\frac{1}{280}$th of an inch in diameter. This increase is not only owing to the granules which appear to be accumulated from the walls of the ovary, but also to an increase in the amount of the clear substance.

Some have supposed the increase in the number of the granules to be owing to their spontaneous division, while others have thought that they are formed by the germinal vesicle. To the first theory it may be objected, that the granules remain very much of the same size throughout, while those contained in the same ovule correspond exactly, which would not be the case if each granule were dividing into two or more. That the granules are not produced by the germinal vesicle is evident from its remaining very much of the same size and perfectly entire.

On the other hand, the reasons for supposing them to be formed from the walls of the ovary are, that the granules become more and more numerous as the ovule passes down the tube. Secondly, that the granules (Plate XXVIII. figs. 48, 51 *c*) exactly resemble in size, colour and form, those produced by the internal surface of the ovary (Plate XXVII. fig. 41 *k*). Lastly, because the striæ (fig. 41 *l*) of the ovary cease just where the ovule ceases to become larger (fig. 42 *h*).

The fact that the ovula were packed edgewise in this part of the tube (Plate XXVIII. fig. 49 *c*) was pointed out to me by Dr. ALLEN THOMSON; also that three or four occupied the same plane (fig. 50 *d*). Hence the necessity of the ovula assuming the triangular form (Plate XXVII. fig. 47); the only form met with as long as the ovula present the appearance of a dense opake mass (Plate XXVIII. fig. 49).

The ovary is about $\frac{1}{120}$th of an inch broad at its widest part; and here it is that we find the ovula packed generally four on a plane (fig. 50 *d*), with their edges presenting externally (fig. 49 *d*), appearing long and narrow when viewed in profile (fig. 49 *c*), but broad and triangular when seen in front (fig. 49 *b*), entirely filling the transverse section of the tube (fig. 50 *w*).

As the granules increase in number so the clear substance becomes more and more obscured, till at length the whole ovule appears to be composed entirely of vitelline granules. The germinal vesicle (fig. 48 *b*) can no longer be distinguished, the ovule being perfectly opake (fig. 50 *d*). In this state they are met with near the entrance of the oviduct (fig. 50 *d*); they now become separated, detached singly from the mass, lose their triangular form (fig. 51), and by passing through the first constriction (Plate XXX. fig. 90 *c*) enter the glandular portion of the reproductive apparatus (Plate XXVII. fig. 42 *n*; Plate XXX. fig. 90 *c*, *d*).

When impregnation has taken place, the ovule first meets with the spermatic particles (Plate XXVII. fig. 42 *p*) in this part of the oviduct (fig. 42 *n*), but I think it may be best to trace the further changes it undergoes in the unimpregnated state, as they enable us to explain, or what is of more consequence, to contrast the appearances presented by the fecundated ovum with those of the non-vivified egg.

As soon as the ovule enters the glandular portion (Plate XXX. fig. 90 *c, d*) it floats free in a clear fluid secreted by the cells lining the oviduct. The ovule becomes thicker and more rounded, losing the flattened form it assumes that of an oblong sphere (Plate XXVIII. fig. 52). A granular chorion (fig. 54 *f*) begins to form, surrounding the ovule and constituting an elastic shell (fig. 55 *f*). While this external chorion is forming, however, the internal contents are undergoing change, the vitelline granules become much smaller in size (fig. 52 *c*), the germinal vesicle and spot disappear, and in their place we find a number of large transparent globules (fig. 53 *e*), having much more the appearance of oil than of being formed by cells. These globules are apparently formed partly by the disappearance of the germinal vesicle, and partly by the separation of the oil from the granules of the vitellus. After a time these oily globules (fig. 54 *e*) approach the circumference and disappear (fig. 55 *e*), while the minute opake particles (figs. 54, 55 *c*) pass towards the centre. The ovule now begins to shrink, the chorion becomes more granular and thicker (fig. 56 *f*), while from its inner surface a delicate membrane separates (fig. 57 *o*), and contracting on the particles contained within it, forms one molecular mass, spherical and perfectly opake (fig. 56 *o*).

This false ovum (fig. 56), if I may be allowed to call it so, is surrounded externally by a peculiar granulated chorion or shell of an irregularly ovoid form (fig. 56 *f*), within which, but separated from it by a clear fluid, is the opake spherical mass already described, with its delicate membrane (fig. 56 *o*). On rupturing one of these false ova, the opake mass is found (fig. 57 *c*) to consist of granules and a few oil-globules. While the fertile egg does not remain stationary but advances, stage after stage, till the worm is produced, the false ovum undergoes no further development, but when expelled from the vagina of the *Ascaris* rapidly decays.

In all those instances in which the spermatic fluid was imperfectly developed, or had not ascended higher than the uterus, false ova alone existed (fig. 56), having all the characters of those just described, and incapable of further change.

From this we may infer, that after the formation of the chorion (figs. 54 to 56 *f*) impregnation of the ovule is impossible; and as the chorion is formed while the egg is yet within the oviduct (Plate XXX. fig. 90 *c, d*), fertilization must take place, if at all, while the ovule is still in the oviduct, and before the formation of that envelope.

Let us now return to the fertile condition of the female, and trace the development of the ovum as it threads the oviduct (fig. 90 *c, d*).

The ovula are here surrounded by the spermatic particles; here it is that fecundation takes place,—by which alone fertile ova can be produced.

This conversion of the ovule into the fertile ovum, I shall endeavour to describe according to my own repeated observations.

Immediately that the ovule passes the constriction which terminates the ovary and enters the oviduct (Plate XXVII. fig. 42 *n*), it comes in contact with the semen (fig. 42 *p*), and a marked change in its form and appearance takes place. It is at this

period of an oblong shape (Plate XXVIII. fig. 58), and appears to be entirely made up of distinct opake granules, which completely hide the germinal vesicle and spot (figs. 58 to 60 *c*).

The edge at first is uniform, that is to say, not ragged, but presents a distinct outline (fig. 58 *d*). Sometimes a faint trace of the germinal vesicle may be perceived (fig. 60 *b*), although the ovule is never so transparent as to allow objects on the other side to be seen through it.

In the upper portion of the oviduct (Plate XXVII. fig. 42 *n*) we find the spermatic particles (fig. 42 *p*) in their greatest perfection (Plate XXVI. fig. 38 *g*), presenting the flask-like appearance, and in such numbers as to fill all the interstices between the ovulum and the sides of the oviduct.

At first the margin of the ovule (Plate XXVIII. fig. 51 *d*) is entire, that is to say, the clear substance presents a distinct, even and continuous surface, but a little further we perceive the spermatic particles to be closely applied against the ovule, depressing its surface in some places (fig. 60 *g*). Another step in advance, and all the ovula present an irregular rupture in some part or other of their periphery (figs. 58 to 60), generally at one side (fig. 58), and frequently in several places at the same time (figs. 59, 60).

Dr. Allen Thomson, having frequently examined these appearances, permits me to say that he agrees entirely with the above description of the phenomena.

That these appearances do not arise from pressure applied during the examination I am perfectly satisfied, having repeated my observations above a hundred times, and varied them so as to remove all possibility of such an occurrence. The effect of pressure on the ovule is also very different from that just described, as I have repeatedly seen; for if an entire ovule be squeezed between glasses, the vitelline granules coalesce, the clear substance dilates, and at last the whole lapses into a yellowish fluid.

From the immense number of ovula in which I have seen this partial rupture of the vitellus, and the want of success in my endeavours to cause a similar protrusion (figs. 58 to 60 *c*) of the yolk-granules by compression, I am irresistibly led to the conclusion that this is a vital phenomenon consequent on some natural cause, and not the result of accidental violence. Further, to make all certain, I divided the oviduct at both ends, washed away all loose ovules by a gentle stream of water, and then superimposed, as carefully as possible, a piece of the thinnest glass. No other pressure than the weight of the thin piece of glass was applied, yet every one of the ovules, as they slowly found their way out of the oviduct, presented in some part or another this rupture of the surface.

The reason why all the granules do not escape, arises from their being imbedded, not in a fluid, but in a sort of gelatinous substance, easily broken up, it is true, but sufficiently coherent to retain the granules in their places.

To what then are these appearances owing, and how are they produced? I have

already said that the spermatic particles become first applied to the periphery of the ovule (Plate XXVIII. fig. 60 g); and that a little later they are seen to indent the surface.

Still lower we find the spermatic particles imbedded in the substance of the ovule to a greater or less degree, and surrounded by the vitelline granules that have been displaced (fig. 58 *g*). Sometimes only one is seen to be thus imbedded (fig. 58*g*), but more commonly several spermatic particles are applied at the same place, with their closed ends directed in general towards the centre (figs. 59, 60 *gg*). Penetration then takes place, the particles passing into the substance of the ovule, amongst the vitelline granules, and surrounded by the clear substance (figs. 59, 60 *h*).

I have seen the spermatic particles in all stages of penetration, from mere contact (fig. 60 *g*) to perfect involvement within the ovule (figs. 59, 60 *h*). In their course they appear to create very little displacement, passing readily in all directions amongst the granules; their transparency and high refractive power rendering them easily distinguishable when near the surface (figs. 59, 60 *h*).

Of the possibility of penetration, no one who has ever seen an ovule of this *Ascaris* can have the slightest doubt, composed as it is of a clear gelatinous substance, without an enveloping membrane; while the very granules it encloses (fig. 51 *c*), there is great reason to believe, have at some period entered from without.

With regard to the probability, there is the breaking up of the surface of the ovule in certain places (figs. 58 to 60 *c*), rendering it still easier for the entrance of the spermatic particles.

Secondly, the application and adhesion of the seminal particles to the broken edge (figs. 58 to 60 *g*).

Lastly, their having been seen (figs. 59, 60 *h*) within the ovule, imbedded in its substance, and surrounded on all sides by the vitelline granules.

As I have shown the possibility and even the probability, it remains only for me to prove the correctness of my observations.

That the spermatic particles seen by me (figs. 59, 60 *h*) might possibly have been external to the ovule, will naturally occur to every microscopic observer. But this doubt is manifestly unfounded, for many reasons.

First. The particles (figs. 59, 60 *h*) could not have been lying upon the ovule, because vitelline granules were visible above them; that is to say, by distancing the object-glass from the object, the spermatic particles became indistinct, and a layer of granules came into focus, entirely covering the space they occupied.

Secondly. They could not have been below, for the ovules are much too opake to be seen through.

Thirdly. The seminal particles observed were only in focus, when the margin of the ovule was in focus, and must therefore have been on the same plane. But, as the ovule is a more or less spherical body, the focus of its margin corresponds with

that of its centre; hence the particles already mentioned could only have existed in the substance of the ovule.

Another objection might be raised; admitting the particles to have been situated in the substance of the ovule, might they not have been oil-globules, like those seen in the unfecundated egg?

The reply to this is most satisfactory; for not only were the particles elongated and cylindrical (figs. 59, 60 *h*), but the one extremity was closed, and the other open; hence they could only have been the spermatic particles of the male.

I cannot enter here upon the consideration of the changes which occur in the mammiferous ovum, but confine myself to a few remarks.

Dr. Martin Barry says, "On one occasion, in an ovum of $5\frac{1}{4}$ hours, I saw in the orifice of the membrane" (the external membrane of the ovum) "an object very much resembling a spermatozoon which had increased in size . . . I am not prepared to say that this was certainly a spermatozoon, but it seems proper to record the observation."

Now, whether we believe Dr. Barry to have really seen the penetration of the spermatozoon into the mammiferous ovum, or whether we agree with Bischoff and most other distinguished authors, and deny the correctness of Dr. Barry's observation, as well as the possibility of any such occurrence, the present investigations appear to be the first in which the fact of the penetration of spermatozoa into the ovum has been distinctly seen and clearly established, in one of the most highly organized of the entozoa.

The accuracy of these observations is satisfactorily borne out, and will be more readily admitted, as we continue to trace the progress of the ovule, the changes of the spermatic particles, and the development of the ovum.

The accompanying drawings present these appearances as exactly as possible, being taken originally from actual specimens, by means of a camera lucida. In some we find the broken margin of small extent (figs. 58, 60 *c*); in others it embraces nearly one half of the circumference (fig. 59 *c*). Some give a faint indication of the contained germinal vesicle (fig. 60 *b*); but in most the granules are too opake to admit of its being seen at all (figs. 58, 59). Let us now pass to the examination of the changes which take place in the ovule subsequent to the penetration of the spermatic particles.

The ovule, it must be remembered, is still in the oviduct; the secretive portion of the system, and that in which the false ova receive an enveloping membrane (figs. 54 to 57 *f*). Almost immediately therefore that the ovule has entered the oviduct, traces of a chorion, as a very delicate membrane, begin to appear (fig. 61 *f*), covering at first those portions only of the surface that remain smooth and entire (figs. 61, 62 *f*); but as we descend, enclosing by degrees the ruptures themselves, and surrounding thus the whole ovule in one continuous envelope (fig. 63 *f*), with

its germinal vesicle, vitelline granules, and the spermatic particles that have penetrated its substance (fig. 63 *h*). Having entered the vitellus in different directions, and to various depths, the spermatic particles (figs. 61, 62 *g*) lose their characteristic form, and swell into irregular masses (figs. 61 to 63 *h*), transparent, presenting a distinct outline, and highly refractive.

These transformed spermatic particles (figs. 61 to 63 *h*), being situated in the midst of the opake granules (figs. 61 to 63 *c*), give the ovum a most peculiar mottled appearance (figs. 62, 63).

That they are spermatic particles cannot be doubted, as we meet with them in all stages of transformation (figs. 61, 62 *g*, *h*); while the regularity in shape presented by the large oil-globules of the false ovum (figs. 53 to 55 *e*) is absent, as well as the running together of the granules (figs. 54, 55 *c*) by which they are formed.

The ovum immediately after the entrance of the spermatic particles (figs. 58 to 60 *g*) begins to acquire a chorion (figs. 61 to 63 *f*). The formation of this chorion does not appear to be dependent at all on the penetration, but to be owing to the ovum having reached that part of the oviduct by which the membrane is secreted, because we find it occurring even in the unfecundated state.

This chorion, however (figs. 61 to 63 *f*), differs from the granular shell of the false ovum (figs. 54 to 57 *f*), in being perfectly smooth, membranous and transparent (figs. 61 to 63 *f*), appearing as a single dark line, imperfect indeed at first, where protrusion of the granules exists (figs. 61, 62 *f*), but gradually encircling the whole ovum (fig. 63 *f*).

When first formed, the chorion is flaccid (fig. 63 *f*), and the ovum appears of an irregular shape (fig. 63); but by the imbibition of fluid it swells up, becomes tense and spherical (Plate XXIX. fig. 64 *f*).

The spermatic particles (Plate XXVIII. figs. 61 to 63 *h*), after becoming enclosed and swollen, begin to disappear (Plate XXIX. fig. 64 *h*), probably by solution, leaving in their place a transparent fluid (fig. 65 *m*).

The vitelline granules that previous to the impregnation of the ovum formed one uniform, opake mass (Plate XXVIII. fig. 58 *c*), and partially broken up (figs. 59 to 63 *c*) by the penetration and swelling of the spermatic particles (figs. 59 to 63 *h*), are now still further excavated, separated, and detached into distinct masses by the solution of those particles (Plate XXIX. figs. 64, 65 *c*). This appears not only to be owing to the solution of the spermatic particles themselves, but to some direct influence that their solution has on the yolk, for many of the granules disappear entirely; while others are changed, both as regards colour and size (fig. 66 *n*), a transformation totally different to that which I have described as taking place in the false ovum (Plate XXVIII. fig. 56 *c*).

Sometimes the whole vitellus is thus broken up (Plate XXIX. fig 65 *c*), giving the ovum a beautifully mottled appearance; but more commonly it is only the surface

that is first affected (figs. 64, 66 *c*), the process of disintegration gradually passing towards the centre.

This mottled appearance (fig. 65) has been noticed by REICHERT in the egg of a *Strongylus*, and ascribed by him to the formation of cells within the yolk, which is certainly not the case in the fertile ova of the *Ascaris mystax*.

When there is much disintegration, the germinal vesicle may be seen with its germinal spot or nucleus (figs. 64 to 66 *b*, *a*), and occasionally within this (figs. 64, 65 *a*), again, another nucleolus (figs. 64, 65 *k*).

But in general the germinal vesicle (figs. 64, 65 *b*) cannot be seen; for, as the erosion of the yolk commences on the surface (fig. 66 *c*) and gradually passes towards the centre, the vesicle is always covered by a layer of opake granules.

As the solution of the yolk goes on, the opake granular mass in the centre becomes less and less, leaving a clear margin of fluid surrounding it on all sides (fig. 66 *c*). Some granules, however, escape, and are seen floating in the fluid; but they are larger in size, and more transparent than the original yolk-granules (fig. 66 *n*).

About this period the ovum acquires another chorion, consisting generally of two membranes, and becomes more elliptical in form.

The three membranes that surround the ovum at this period, as they are all formed in the same way, and are exactly alike, may be considered as three layers of the same chorion (fig. 66 *f*), secreted at different times by the oviduct.

When the granular mass has been much reduced in size (fig. 66 *c*) it suddenly loses its opacity; and thus the whole vitellus is transformed into a few large, nearly transparent granules (fig. 67 *n*), among which we look in vain for a germinal vesicle; and only now and then are we able to distinguish one granule to be a little larger than its fellows (fig. 67 *a*), and to contain within it a dark spot (fig. 67 *k*).

In short, the germinal vesicle (figs. 64 to 66 *b*) ruptures, when disintegration has gone on to a certain length, and its disappearance is immediately followed by the transformation of the remaining vitelline granules.

I propose to call these transformed or altered granules by the name of embryonic granules (figs. 67, 68 *n*), since they appear about the same time as the embryonic vesicle, and with it assist in forming the embryo.

After the rupture of the germinal vesicle (figs. 64, 65 *b*), the interior of the egg is filled with the embryonic granules (fig. 67 *n*), not, however, packed close like the vitelline, but floating loose. About the centre of these granules, one a little larger than the rest (fig. 67 *a*) may sometimes be seen, having within it an opake spot (fig. 67 *k*). On comparing these with the nucleus and nucleolus of the germinal vesicle (fig. 64 *a*, *k*) before its rupture (fig. 64 *b*), I found them to resemble each other completely, having the same size, shape, and appearance, the same degree of refraction, and the same position.

The germinal vesicle immediately before its rupture (figs. 64, 65 *b*) is $\frac{1}{1000}$th of an

inch in diameter; its nucleus, or as it is commonly called, the germinal spot (figs. 64, 65 *a*), is $\frac{1}{4000}$th of an inch, and the contained nucleolus $\frac{1}{8000}$th of an inch (figs. 64, 65 *k*).

After the rupture, the nucleus and nucleolus (fig. 67 *a*, *k*) are of exactly the same size, $\frac{1}{4000}$th and $\frac{1}{8000}$th of an inch respectively.

But soon the nucleus, which is at first solid (fig. 67 *a*), begins to enlarge, swells up, and constitutes a transparent cell (fig. 68 *a*); while the nucleolus remains of the same size (fig 68 *k*), forming, in short, an embryonic vesicle and spot.

As soon as the embryonic vesicle (fig. 68 *a*) begins to form, a membrane separates from the internal surface of the chorion (fig. 69 *f*), and gradually contracts (fig. 69 *o*) on the embryonic granules (fig. 69 *n*), till a perfect sphere is formed, whose breadth is nearly equal to the lesser internal diameter of the ovum (fig. 70 *o*).

How, or from what this membrane (fig. 70 *o*) is formed, I cannot speak with certainty, further than that it separates from the inner surface of the chorion (fig. 69 *f*), and contracts on the embryonic granules (fig. 69 *n*) to form a true or embryonic yolk, exactly in the same way that it does (Plate XXVIII. fig. 56 *o*) in the false ovum (fig. 56) to form the opake or false yolk (fig. 56 *c*).

It is probable, therefore, that the formation of the yolk-membrane (Plate XXIX. fig. 70 *o*) is a physical process, unconnected with the fertility, or the individual vitality of the egg, as it takes place exactly at the same time, and in the same manner in the unfecundated or sterile ovum, into which the spermatic particles have never entered.

When the membrane of the embryonic yolk first separates from the inner surface of the chorion, it encloses not only the embryonic granules (fig. 69 *n*), vesicle (fig. 68 *a*) and spot (fig. 68 *k*), but likewise the clear fluid in which they float; although, as contraction goes on, this fluid passes through the membrane (fig. 70 *o*) and occupies the space between it and the external envelopes (fig. 70 *f*). It therefore acts the part of a sieve, allowing the fluid to pass, but retaining the granules, and bringing them within the influence of the embryonic vesicle (fig. 70 *a*).

The embryonic yolk is at first large and irregular in shape (fig. 69 *o*), but it soon becomes perfectly spherical (fig. 70 *o*), $\frac{1}{600}$th of an inch in diameter, enclosing an embryonic vesicle and spot, whose sizes are $\frac{1}{2000}$th and $\frac{1}{6000}$th of an inch respectively (figs. 70 *a*, *k*).

At this period the egg (fig. 70) is oval, its longer diameter being $\frac{1}{310}$th of an inch, and its shorter $\frac{1}{350}$th of an inch; its membranes are firm and resisting (fig. 70 *f*); and with this amount of organization it is expelled from the body of the mother.

The perfect ovum, therefore, consists of two or three homogeneous membranes, united to form one oval shell (fig. 70 *f*), some limpid fluid (fig. 70 *m*), a spherical embryonic yolk membrane (fig. 70 *o*), embryonic granules (fig. 70 *n*), an embryonic vesicle (fig. 70 *a*), and its nucleus, the embryonic spot (fig. 70 *k*).

Compare the fecundated (fig. 70) with the unfecundated ovum (Plate XXVIII. fig. 56), and one is immediately struck with the immense difference that exists between them.

In the false ovum there is no embryonic vesicle, no embryonic spot; while the substance that does exist, is apparently the colouring matter of the vitelline granules, collected into a structureless yolk (fig. 56 *c*), surrounded by a membrane (fig. 56 *o*), and the whole enclosed in a granular chorion (fig. 56 *f*) instead of a laminated shell (Plate XXIX. fig. 70 *f*).

The formation of the embryonic yolk membrane is not the effect of fecundation (fig. 70 *o*), because we see one produced in the sterile ovum; but after the entrance, swelling up, and solution of the spermatic particles, certain other changes are produced within the ovule, which do not occur otherwise.

The spermatic particles, by penetrating into the ovule, exert over it an influence of three distinct and somewhat opposed kinds.

First. A preservative effect, preventing the decay, disappearance, and blending together of the vitelline granules, the germinal vesicle and spot.

Secondly. A destructive or solvent influence, by which the vitelline granules and germinal vesicle are, after a time, gradually dissolved.

Thirdly. A power of transformation, by which the vitelline are changed into embryonic granules.

The preservative, destructive and transformative influences commence, as we have seen, with the union of the spermatic particles and ovule; they are conferred by the spermatic particles on the ovule, which continues to exist, while the sperm is destroyed by the act; and lastly, they appear all three to be of a purely chemical nature.

These properties once acquired, continue not only throughout the whole life of the creature, but remain after the death of the individual.

To one or other of these influences may all the changes that take place in the living body be ascribed, with the exception of those that are referrible to life alone.

But before entering on the consideration where life commences, and in what part it resides, it is essentially necessary that we make ourselves acquainted with the changes it effects in the ovum, by which the egg is transformed into an embryo, in all respects similar to the parent *Ascaris*; like it, capable of voluntary motion, assimilation, and the power to produce other ova.

These are most beautifully seen in the egg of the *Ascaris mystax*; but as they have been already described by far abler authors, I shall confine myself to a very brief outline of the changes as they occurred under my own observation.

The first alteration that the ovum undergoes is the division of the embryonic spot (Plate XXIX. fig. 72 *k*), and elongation of the embryonic vesicle (fig. 72 *a*).

This division is sometimes seen even before the germinal vesicle has disappeared (fig. 65 *k*), but does not take place normally till after the formation of the true or embryonic yolk (fig. 70 *o*).

The division of the nucleus (fig. 72 *k*) is immediately followed by that of its cell, the embryonic vesicle (fig. 73 *a*); and thus two embryonic vesicles are formed, each containing a separate nucleus or spot (fig. 73 *k*).

As soon as this has occurred, the two cells (fig. 73 *a*) are seen to separate and approach the opposite sides of the yolk; a portion of the yolk membrane (fig. 73 *o*) is protruded outwards, by the application of one of the embryonic cells against it. At first this protrusion is very slight (fig. 73 *o*), but by the continued movements of the vesicle (fig. 74 *a*) it becomes more and more increased, till at last the yolk assumes an oblong shape, with a constriction about the middle (fig. 74 *o*). The constriction gradually deepens, till at last two yolks are formed (fig. 75 *o*) by the sudden division of the investing membrane.

I have repeatedly watched this process as it occurred under the microscope, and found that while the division of the embryonic vesicles takes from five to ten hours, the division of the yolk does not take more than thirty minutes.

The separation of the yolk into two parts is, I think, entirely a mechanical effect, and not produced by vitality inherent either in the yolk-granules (fig. 75 *n*) or membrane (fig. 75 *o*). For, besides the rapidity of its accomplishment, I have observed that the embryonic vesicles (figs. 73, 74 *a*) continue during the progress of the division to revolve round and round in circles; the one moulding the newly projected portion of the yolk membrane (figs. 73, 74 *o*) into a spherical form, while the other prevents the original part from collapsing.

Sometimes, when the formation of a yolk has been prevented by immersion in some preservative fluid, the division of the embryonic vesicle still takes place (fig. 71 *a*), and the two are generally seen occupying opposite ends of the egg, but without any membranous or granular investment.

As soon as the yolk has divided into two (fig. 75 *o*), a pause occurs. The two embryonic vesicles (fig. 75 *a*) remain stationary, their nuclei (fig. 75 *k*) subdivide, they themselves elongate, and ultimately separate into two each. Thus four embryonic vesicles are formed, two within each yolk mass, which, by the repetition of the same process, is redivided into four (fig. 76 *o*).

Occasionally, when one embryonic vesicle divides more rapidly than its fellow, three yolk masses are produced; but this is rare, and not usually the case.

As this process is repeated from time to time, the number of the yolk masses increases from 4 (fig. 76 *o*) to 8, 16, 32, 64, 128, 256, &c., till they (fig. 77 *o*) become so numerous and so minute as to appear like granules (fig. 78 *o*); yet each granule (fig. 78 *o*) is composed of a nucleus, an embryonic cell, yolk substance, and yolk-membrane.

From the immense amount of subdivision and the number of interspaces caused by the spherical form of the granules, the whole egg is filled with them, giving it a dark or opake appearance (fig. 78).

A membrane appears to form on the external surface of this opake mass, corre-

sponding to the internal surface of the chorion; the production of which is attended with a loss of some of the most superficial granules.

Next, a depression (fig. 79 *p*) of this membrane takes place on one of the sides.

The depression is at first slight (fig. 79 *p*), but it gradually increases, forcing some of the granules before it, while others disappear by solution into a limpid fluid, which, passing through the membrane, occupies the space between it and the shell (fig. 79 *r*).

A hemispherical mass is thus produced, but the central portion continues to advance, forming first a cup-like depression (fig. 80 *p*), and, ultimately touching the membrane of the opposite or convex side, unites with it, to produce a thick circular ring (fig. 81 *p*).

This fleshy ring (fig. 81 *p*) soon presents a constriction at one point (fig. 82 *s*). The constriction, by deepening, divides the ring, which is thus transformed into a cylindrical worm, bent round, so that the two ends are in apposition (fig. 83 *s*); and covered externally with the membrane (fig. 83 *p*), now become thick, while internally we still see nothing but granules (fig. 83 *o*).

As the body elongates, the two ends overlap, and are seen to be pointed. At first the overlapping is slight (fig. 83 *s*), but it gradually increases (Plate XXX. figs. 84, 85, 86 *s*), till at length the little worm forms nearly two turns of a spiral (figs. 87, 88 *p*), surrounded on all sides by fluid (figs. 87, 88 *r*) and the chorion, or shell (figs. 87, 88 *f*).

By rupturing the egg, the embryo worm is set free (fig. 89), and is seen to possess the three-lobed mouth (fig. 89 *s*), peculiar to the genus, and a very thick cuticle (fig. 89 *p*) enclosing a number of untransformed granules (fig. 89 *o*).

The development of the embryo is best observed by placing the females entire in spirits of turpentine for a fortnight or three weeks; at the end of which I have found the ovaries distended with ova, all of which contained young worms, not only fully developed (figs. 84 to 88), but alive, endeavouring their utmost to rupture the chorion, by rolling themselves up into a tight spiral (fig. 88 *p*), and then suddenly reversing the coil.

Let us now return to the consideration as to which of these changes are vital, and which physical.

The most remarkable, as well as most apparent change that takes place in the ovum subsequent to penetration, is the division of the yolk, a phenomenon, which, although peculiar, seems to be entirely mechanical.

For the yolk membrane when at rest, as seen before the division of the yolk, assumes the spherical form, by its own molecular attraction (Plate XXIX. fig. 70 *o*); but when drawn out by the embryonic vesicles, acquires first a cylindrical shape, then that of an hour-glass, because that part of the membrane occupying the centre of the cylinder, having nothing to keep it distended, collapses; while the two ends are prevented from doing the same by the constant movements of the embryonic vesicles (fig. 74 *a*).

When the hour-glass form (fig. 74 *o*) has been once attained, the molecular attrac-

tion of the membrane tends no longer to draw it into a single sphere, but into two globules; and thus the division of the yolk is completed.

This view is further confirmed by the fact, that while the first steps of this process take, comparatively speaking, a long time, as soon as the hour-glass form has been once acquired, complete division is effected so suddenly that it is invisible; while a violent oscillatory motion is from the same cause communicated to the yolk masses, taking some little time to subside.

The division and movements of the embryonic vesicle, on the contrary, can only be ascribed to vitality.

That this division cannot be produced by the action of the spermatic particles on the embryonic vesicle, is evident from the fact, that it does not take place from without inwards, but from within outwards. The embryonic spot divides first; and this I have even seen to take place before the germinal vesicle has been ruptured, while it was still entire (fig. 65 *k*), and consequently long before the seminal fluid could possibly exert any influence over its nucleoli, imbedded as they are in the substance of the yet solid nucleus (fig. 65 *a*), surrounded by fluid, and protected by the germinal vesicle (fig. 65 *b*).

The fissiparous growth of the embryonic spot proves beyond a doubt that its division is caused by vitality inherent in it.

The embryonic vesicle, although owing its division to the nuclei it encloses, is also alive, because it grows in size, and when divided we see it move, not as some suppose, by mere electric repulsion; for I have most distinctly seen it continue to revolve in different directions, and in circles of various diameter.

I am inclined to the belief that these movements of the embryonic vesicles are caused by vibratile cilia, from a certain amount of commotion among the yolk granules immediately surrounding the vesicle, observable only when the latter is in motion.

But the embryonic vesicle and spot are nothing else than the nucleus and nucleolus of the germinal vesicle. Is this, then, alive? Yes: because, when first thrown off by the ovary as a germinal particle (Plate XXVII. fig. 39 *c*), it is solid; the external layer of which by growth forms a vesicle (fig. 39 *d*), while the interior remains solid some time longer, and constitutes its nucleus (fig. 39 *f*).

This nucleus has been already shown to possess vitality, and as it exists in the germinal particle, it also must be alive.

The growth of the germinal vesicle, therefore, from the germinal particle, is as vital as the growth of the embryonic vesicle from its nucleus, the germinal spot.

We have seen that life does not originate at the period of fecundation; we have traced the vitality possessed by the ovum as far back as the very commencement of the ovule; we must therefore admit that it is derived from the mother.

For as the germinal particle is living when thrown off by the ovary, and as the

ovary, being part of the female, shares her life, the vitality possessed by the germinal particle can only be derived from that of the mother.

From this, it appears that the embryo or young *Ascaris mystax* obtains its vitality solely from the mother, but that certain conditions are necessary for the continuance, maintenance and development of that life; and that these conditions are alone furnished by the changes effected by the product of the male, on the matters immediately surrounding the living cell.

When the male secretion is not present, when the above conditions are not fulfilled, life ceases; the vital point dies; and although the surrounding substance does not immediately perish, yet it no longer encloses a germinal vesicle, or even a germinal spot.

Finally, I would desire to draw attention to the beautiful analogy that exists between the products of the ovarian and testicular tubes. The cæcal extremities, of both the male and female reproductive systems, throw off solid particles of the same size, shape and appearance; both kinds soon present spots in their centres, and both swell up into nucleated cells. Yet the one is a seminal, and the other a germinal vesicle.

Granules are now accumulated round both. Both might be called ovules with equal propriety; so analogous are they in structure, that size alone distinguishes them. But the one is an ovule, and the other a granular mass.

The granular matter of the ovule dissolves, the germinal vesicle enlarges and disappears, setting free its nucleus.

The seminal mass likewise loses its granular covering; the seminal vesicle enlarges, and by disappearing, its nucleus is also set free.

Thus far the analogy is complete, but here it ends; the transformed nucleus of the male cell enters the granular vitelline substance of the female ovule, perishing by solution; while the nucleus of the germinal vesicle enlarges, divides, subdivides and redivides, till a mass of granules are formed, each possessed of an individual existence, and together capable of producing a living whole; a worm in every respect like its parent, endowed, like it, with the powers of assimilation, locomotion, and reproduction.

A new life therefore is not generated during the development of a new being, by the happy combination of physical forces; but the same life bestowed by God at the creation, continues without intermission, transmitted from mother to offspring, pervading and redeveloping itself in each individual member of the species.

Explanation of the Plates.

PLATE XXV*.

Fig. 1. Head of *Ascaris mystax*. *a*. The lateral ala or moustache, finely striated. *b*. The mouth with its three lips. *c*. The intestine commencing narrow at the mouth, and passing in a straight line along the axis of the body. *d*. The striated or horny bands of cuticle covering the body. Magnified 30 diameters.

Fig. 2. Tail of male. *a*. The dorsal aspect. *b*. The ventral. *c*. The anus. *d*. The genital orifice. *f*. Membranous projections, serrated on the edge and supported by tubercles. *g*. Spiculæ protruded to the natural extent. Magnified 30 diameters.

Fig. 3. Male *Ascaris mystax*, natural size. *a*. The tail coiled up on the ventral aspect.

Fig. 4. Female, natural size. *a*. The tail, not coiled, and coming to a blunt point.

Fig. 5. Reproductive apparatus of the male. *a*. The convex dorsum of the tail. *b*. The concave ventral surface. *c*. The anus. *d*. The genital orifice. *f*. The part of the spiculum which is never protruded naturally, and is covered with tubercles for the attachment of the protractor and retractor muscles. *g*. The horny opake portion of the spiculum, which is protruded in coitus. *h*. The sheath of the spiculæ into which they are withdrawn when not employed. *i*. The inferior portion of the intestinal canal. *k*. The seminal vesicle, covered by a reticulation of muscular fibres. *m*. The vas deferens. *n*. The testicular tube, filled with semen. *o*. The cæcal extremity of the testicle. Magnified 20 diameters.

Fig. 6. Part of the spiculum. *a*. The protrusive portion, opake and tubular. *c*. The cartilaginous or non-protrusive portion, semi-transparent and of larger calibre than the horny. *d*. The tubercles to which muscles are attached. *f*. The joint between the two portions of the spiculum.

Fig. 7. Part of the spiculum. *a*. The horny portion. *b*. The opening through which the semen escapes.

Fig. 8. The cæcal extremity of the testicle. *a*. The thick granular membrane of the extremity from which the seminal particles are thrown off. *b*. The transparent and thin membrane of the testicular tube. *c*. The inner surface of the thickened extremity, showing its granular and irregular aspect. *d*. The seminal particles as they are first thrown off. Magnified 330 diameters.

Fig. 9. Upper portion of the testicle. *b*. The membranous wall beginning to be slightly granular. *a*. The granules thrown off by the walls of the testicle.

d. The seminal vesicles with an enclosed nucleus. *f.* The seminal vesicle surrounded by the granules in a very irregular manner. Magnified 330 diameters.

Fig. 10. Lower portion of the testicle. *a.* The granular or seminal masses more or less formed. *b.* The walls of the tube presenting striæ as well as granules. Magnified 330 diameters.

Fig. 11. Portion of the vas deferens, showing the muscular or contractile fibres that encircle it. Magnified 330 diameters.

PLATE XXVI.

Figs. 12—15. Drawings representing the formation of the spermatozoon in the *Ascaris acuminata.* Copied from WAGNER and LEUCKARDT's article on 'Semen' in TODD's Cyclopædia. *a.* The nucleus of the seminal cell, which by elongation constitutes the tail. *b.* The seminal cell, which is persistent and forms the body of the spermatozoon.

Fig. 16. Formation of the seminal cells, copied from KOLLIKER. *a.* The four seminal cells formed within. *b.* The mother-cell.

Fig. 17. Fully-formed spermatozoon of the *Ascaris acuminata* after REICHERT. *a.* The seminal cell. *b.* The indefinite nucleus. *c.* The enlarged nucleolus. Magnified 300 diameters.

Fig. 18. Contents of the upper part of the testicle. Magnified 500 diameters. *a.* The seminal or spermatic cells. *b.* The granular fluid in which they float. *d.* The nucleus.

Fig. 19. Granular seminal masses in an imperfect state of formation. *a.* The irregular mass of granules. *b.* The enclosed spermatic cell. *c.* A mass subjected to pressure, by which it is resolved into a granular fluid. Magnified 500 diameters.

Fig. 20. Granular masses fully formed. *a.* The perfect mass, presenting nothing but granules and quite opake. *b.* Masses subjected to pressure, showing the contained spermatic cell. *c.* Nucleated spermatic cells set free by pressure. *d.* A spermatic cell, which, having escaped from its granular envelope, has swollen up to several times its former size. Magnified 500 diameters.

Fig. 21. Spermatic cell seen in front. *a.* The transparent delicate cell-wall. *b.* The discoidal, granular and opake nucleus. *c.* The nucleolus.

Fig. 22. Spermatic cell seen in profile. *a.* The cell-wall. *b.* The granular nucleus now appearing lenticular. *c.* The nucleolus. *d.* The membrane covering the internal surface of the nucleus, apparently a portion of the cell-wall.

Fig. 23. Spermatic cell seen in profile. The nucleus *b* enlarged and having lost its

internal limiting membrane. *f.* The nuclear membrane formed at the expense of the outermost granules of the nucleus.

Figs. 24—27. Spermatic cells in various stages. *a.* The cell-wall more or less protruded. *b.* The nucleus. *f.* The nuclear membrane, which, by increasing most at the centre, has forced the cell-wall out.

Figs. 28—30. Spermatic cells. *a.* The cell-wall recovering its protrusion. *b.* The nucleus, becoming smaller and more surrounded by the nuclear membrane. *f.* The nuclear membrane become tubular and bent by the elasticity of the cell-wall.

Figs. 31—34. Spermatic cells. *a.* The cell-wall now become spherical. *c.* The nucleolus still persistent. *f.* The nuclear membrane, first cup-shaped, then conical, and lastly tubular.

Figs. 35, 36. Spermatic cells in the last stage. *a.* The cell-wall. *b.* The remains of the nuclear granules. *c.* The nucleolus. *f.* The nuclear membrane, now become tubular or flask-shaped, adapting itself to the curve of the cell-wall.

Fig. 37. Spermatic particles in a state of imperfect development. *b.* The nuclei of spermatic cells set free. *c.* The nucleoli of the same. *f.* The nuclear membrane in various degrees of perfection.

Fig. 38. Perfect spermatic particles. *b.* The remaining granules of the nucleus. *c.* The nucleoli. *f.* The fully-formed nuclear membranes or spermatic particles. *g.* Their open mouths.

Figs. 21—38. Magnified 500 diameters.

PLATE XXVII. Magnified 330 diameters.

Fig. 39. The commencement of the ovary. *a.* The cæcal extremity, composed of a thick, semiopake granular membrane, from the internal surface of which the germinal particles are thrown off. *b.* Apparent invaginations, probably formed by casts of the cæcal extremity thrown off at intervals. *c.* The solid germinal particles as first thrown off. *d.* The germinal vesicle formed by the swelling up of the external surface of the germinal particle. *f.* The germinal spots or the central portion of the solid germinal particle. *g.* Large opake yolk-granules floating free. *h.* The delicate homogeneous and transparent membrane forming the upper portion of the ovarian tube.

Fig. 40. Portion of the ovary. *d.* The germinal vesicles. *h.* The membranous tube, giving indications of striæ and granules. *k.* The granules thrown off by the ovary to form the vitellus.

Fig. 41. Middle portion of the ovary. *h.* The external homogeneous membrane. *k.* The granules contained within. *l.* The striæ.

Fig. 42. The upper constriction, or that between the ovary and oviduct. *h.* The external membrane of the lower portion of the ovary without striæ. *m.* The constriction where the ovary ends and the oviduct commences. *n.* The transverse striæ of the oviduct, by which the ovules are forced along singly. *o.* An ovule detached from the general mass filling the ovary, and about to enter the oviduct. *p.* The spermatic particles fully developed, occupying the whole length of the oviduct.

Fig. 43. A small portion of the uterus. *h.* The external transparent and structureless membrane. *r.* Large flat cells by which it is lined. *s.* The nuclei, and *t.* The nucleoli of these cells.

Fig. 44. Contents of the cæcal portion of the ovary. *a.* The germinal spot, which is solid. *b.* The germinal vesicle, transparent, containing a fluid and the germinal spot. +. The germinal particle as first thrown off, the swelling up of whose outer layer forms the germinal vesicle, while the central portion remains unaltered to form the germinal spot.

Figs. 45, 46. Ovula at a very early stage of development. *a.* The germinal spot. *b.* The germinal vesicle, whose margin however is not visible. *c.* The vitelline granules surrounding the vesicle, and apparently the produce of the walls of the ovary. *d.* The clear gelatinous substance in which the granules are imbedded, and which forms the margin of the ovule.

Fig. 47. An ovule further advanced, of a triangular form. *a.* The germinal spot. *b.* The germinal vesicle. *c.* The vitelline granules. *d.* The clear substance forming a distinct outline.

PLATE XXVIII. Magnified 330 diameters.

Fig. 48. An ovule still further developed, presenting a discoidal form. *a.* The germinal spot. *b.* The germinal vesicle. *c.* The vitelline granules. *d.* The clear substance.

Fig. 49. Mass of ovules squeezed out of the ovary. *b.* Ovula seen on their flattened surface, and showing the contained germinal vesicles. *c.* Ovula in the natural position they occupy in the ovary, presenting only their edges externally. *d.* The external portions of the flat ovules, which lie against the wall of the ovary.

Fig. 50. Portion of the ovary at its inferior extremity, showing the disposition of the contained ovules. *d.* Four ovula forming one plane, and exactly filling the transverse section of the ovarian tube. *w.* The wall of the ovary containing a few granules.

Fig. 51. A fully developed ovule, of an elliptical or ovoid form, and in the state in which it leaves the ovary to enter the oviduct. *c.* The vitelline granules,

too opake to allow the germinal vesicle to be seen. *d.* The clear substance forming a distinct and clear outline or margin to the ovule.

Fig. 52. An unfecundated ovule, which having entered the oviduct has begun to alter. *c.* The vitelline granules which have begun to coalesce, and have lost their granular character entirely. *d.* The margin of the clear substance.

Fig. 53. An unfecundated ovule, in which the vitelline granules have wholly disappeared, their oily portion having run together into large globules. *e.* The large oil-globules thus formed. *d.* The margin of the clear substance still distinct.

Figs. 54, 55. An unfecundated ovule further changed, by which the oil-globules have begun to disappear, and the colouring matter of the original vitelline granules to approach the centre; while the whole ovule has become enclosed in a chorion. *c.* The colouring matter of the vitelline granules. *e.* The oil-globules. *f.* The granular chorion of the unfecundated ovum, which is secreted by the oviduct.

Fig. 56. An unfecundated or false ovum at its maximum degree of organization. *c.* The colouring matter of the vitelline granules collected into an opake or false yolk, but containing no germinal vesicle or spot. *f.* The granular chorion or shell so characteristic of the false ovum. *o.* The yolk-membrane, that, separating from the interior of the chorion, contracts on the colouring matter to form the spherical opake yolk.

Fig. 57. A false ovum ruptured by pressure. *c.* The colouring matter, which, with a few oil-globules, formed the opake yolk. *f.* The granular chorion. *o.* The yolk-membrane.

Fig. 58. An ovule during fecundation. *c.* The vitelline granules displaced by the application of a spermatic particle. *d.* The clear substance presenting a distinct margin all round the ovule, except where the protrusion of the granules has taken place. *g.* A spermatic particle which is on the point of entering the vitellus, being partially imbedded in its substance.

Fig. 59. An ovule during fertilization, whose vitellus is much broken up by the spermatic particles. *c.* The vitelline granules displaced by the spermatic particles. *g.* The spermatic particles which are entering the substance of the ovule. *h.* The spermatic particles that have penetrated and become wholly imbedded in the substance of the vitellus.

Fig. 60. An ovule during fecundation, presenting more than one rupture of the surface and more transparent than usual. *b.* The germinal vesicle, generally invisible at this period. *c.* Protruded vitelline granules. *g.* Spermatic particles applied against the surface of the ovule. *h.* Spermatic particles that have entered the vitellus.

Figs. 61, 62. Fertile ova, in which the penetration of the spermatic particles has

nearly ceased and the formation of a chorion begun. *c.* The vitelline granules much broken up. *f.* The first layer of the chorion, perfectly transparent and structureless. *g.* The spermatic particles entering at those places in which the chorion is as yet imperfect. *h.* The spermatic particles, which having entered have begun to swell, giving the vitellus a mottled appearance.

Fig. 63. A fertile ovum, with the chorion entire. *c.* The vitelline granules much broken up round the margin. *f.* The chorion, which has wholly encircled the ovum. *h.* The swollen spermatic particles.

PLATE XXIX. Magnified 330 diameters.

Fig. 64. Ovum become spherical either from the external imbibition of fluid or the liquefaction of the contained granules. *a.* The germinal spot. *b.* The germinal vesicle slightly enlarged, and become visible by the breaking up of the vitellus. *c.* The vitelline granules much broken up, and partially dissolved. *f.* The chorion become tense and spherical. *k.* The embryonic spot seen within the germinal spot, forming the nucleolus of the germinal vesicle. *h.* The swollen and partially dissolved spermatic particles.

Fig. 65. Ovum beginning to assume the oval form. *a.* The germinal spot. *b.* The germinal vesicle. *c.* The vitelline granules broken up into detatched masses. *k.* Two embryonic spots seen within the germinal spot. *m.* Fluid resulting from the solution of the spermatic particles and vitelline granules.

Fig. 66. Ovum still containing a germinal vesicle. *a.* The germinal spot. *b.* The germinal vesicle. *c.* A few vitelline granules surrounding the vesicle. *f.* The three layers of the chorion. *n.* The transformed or embryonic granules.

Fig. 67. Ovum in which all traces of the vitellus and germinal vesicle have disappeared. *a.* The germinal spot set free by the disappearance of its vesicle, but still solid. *f.* The chorion. *k.* The embryonic spot enclosed within the germinal spot. *n.* The transformed or embryonic granules floating free in a clear fluid.

Fig. 68. Ovum with the first trace of an embryonic vesicle. *a.* The embryonic vesicle formed by the swelling up of the germinal spot. *k.* The embryonic spot. *n.* The embryonic granules still free.

Fig. 69. Ovum with the separation of a yolk-membrane. *f.* The three layers of chorion. *n.* The embryonic granules. *o.* The yolk-membrane separating from the interior of the chorion, and contracting irregularly on the embryonic granules.

Fig. 70. A perfect ovum, in which state it is expelled from the vagina of the female.

a. The embryonic vesicle. *f*. The chorion. *k*. The embryonic spot. *m*. Clear fluid filling the space between the yolk and the chorion. *n*. The embryonic granules. *o*. The yolk-membrane become spherical, and enclosing the granules.

Fig. 71. An imperfect ovum placed in creosote water, by which the separation of a yolk-membrane was prevented, and yet the embryonic vesicle divided. *a*. The two divisions of the embryonic vesicle occupying opposite extremities of the egg, but without any membranous or granular investment.

Fig. 72. A perfect ovum, in which the embryonic spot has divided. *a*. The embryonic vesicle elongated. *k*. The divisions of the embryonic spot.

Fig. 73. Ovum in which the embryonic vesicle has divided and the protrusion of the yolk-membrane commenced. *a*. The divisions of the embryonic vesicle. *k*. Their embryonic spots. *o*. The protruded portion of the yolk-membrane.

Fig. 74. Ovum whose yolk presents the hour-glass appearance. *a*. The embryonic vesicles, which by constant gyrations have forced the yolk-membrane into an hour-glass shape. *o*. The yolk-membrane constricted in the middle by its own elasticity.

Fig. 75. Ovum, with the yolk divided into two. *a*. The embryonic vesicles. *k*. Redivisions of the embryonic spots. *n*. The two yolks. *o*. The divisions of the yolk-membrane, caused by the joint operation of its own elasticity and the traction of the embryonic vesicles.

Fig. 76. Ovum whose yolk has divided into four. *o*. The four portions of the yolk.

Fig. 77. Ovum whose yolk has divided into thirty-two. *o*. The divisions of the yolk.

Fig. 78. Ovum the whole interior of which is filled with the granules formed by often-repeated division of the yolk. *o*. The granules thus formed.

Fig. 79. Ovum in which the embryonic membrane or cuticle of the worm is first seen. *p*. The depressed portion of the membrane. *r*. The fluid filling the interspace between the membrane and the chorion.

Fig. 80. Ovum in which the depression of the embryonic membrane has given a cup-like form to the mass of subdivided granules. *p*. The depressed portion of the embryonic or cuticular membrane.

Fig. 81. An ovum in which the two sides of the cuticular membrane having united, a fleshy ring has been formed. *p*. The united portion of the cuticular membrane.

Fig. 82. An ovum where the fleshy ring begins to present a constriction at one point. *s*. The constriction.

Fig. 83. An ovum in which the head and tail of the worm are visible. *o*. Untransformed granules. *p*. Cuticular membrane covering and giving shape to the worm. *s*. The head and tail of the embryo.

PLATE XXX.

Fig. 84. Ovum enclosing an embryo. *s*. The overlapping extremities. Magnified 330 diameters.

Figs. 85, 86. Ova containing young worms variously coiled. Magnified 330 diameters.

Figs. 87, 88. Ova in which the worms have arrived at the period of hatching. *f*. The three layers of the chorion. *p*. The worm enclosed in its cuticle, forming nearly two turns of a spiral, by reversing which, the chorion is ruptured. *r*. Clear fluid surrounding the worm. Magnified 330 diameters.

Fig. 89. The embryo worm just escaped from its shell. *o*. The untransformed granules which constitute its body. *p*. The thick enveloping cuticle. *s*. The three-lobed mouth. Magnified 330 diameters.

Fig. 90. The glandular portion of the female reproductive apparatus in which the ovula are fertilized. Magnified 40 diameters. *b*. The lower portion of the ovary filled with an opake mass of ovules. *c*. The first or upper constriction, between the ovary and the oviduct, and indicating the origin of the oviduct. *d*. The lower or second constriction, being the spot where the oviduct terminates by entering the uterus. *f*. The fundus of the uterus filled with ova in various stages of development.

Fig. 91. Portion of the body of a female *Ascaris mystax*, showing the orifice of the vagina. *a*. The simple circular opening, by which the vagina terminates. Magnified 60 diameters.

Fig. 92. The whole reproductive apparatus of the female *Ascaris mystax*, natural size. *a*. The delicate cæcal extremities of the ovaries. *b*. The lower portions of the ovarian tubes filled with ovules, and opake. *c*. The commencement of the oviduct. *d*. The termination of the same. *f*. The two uteri distended with ova. *g*. The single tapering vagina formed by the union of the two uteri.

Fig. 1 — Fixed lines of the solar spectrum in the extreme violet, and in the invisible region beyond.

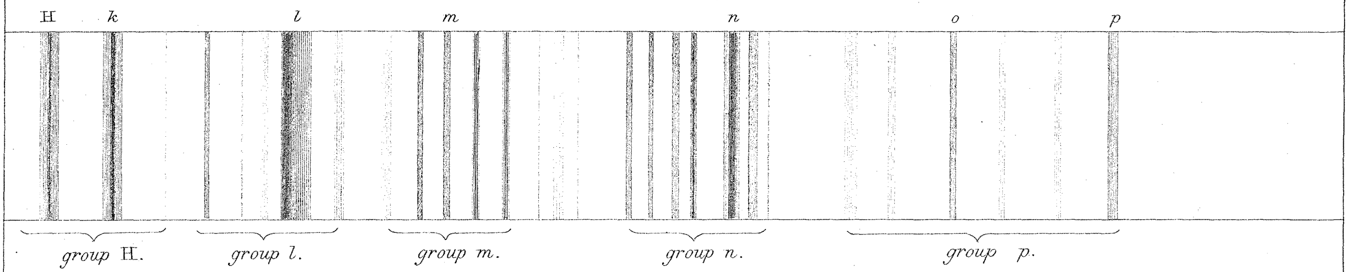
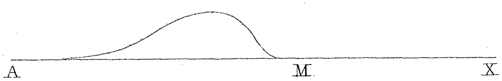


Fig. 2. — Art. 81.



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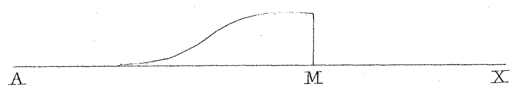

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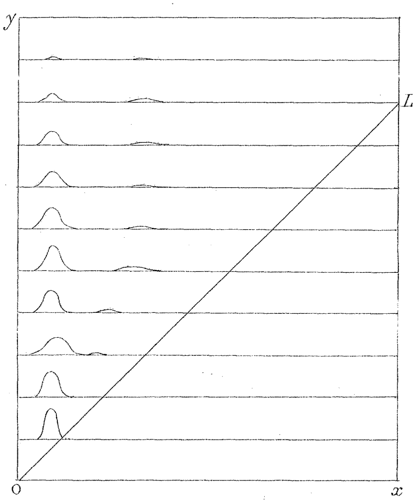
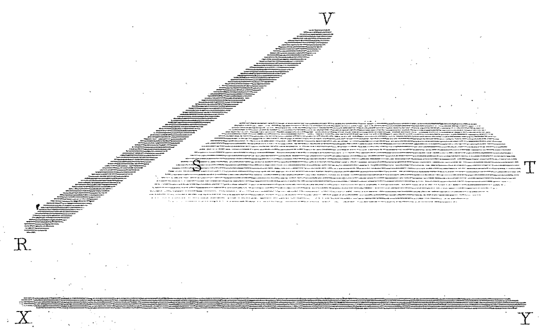
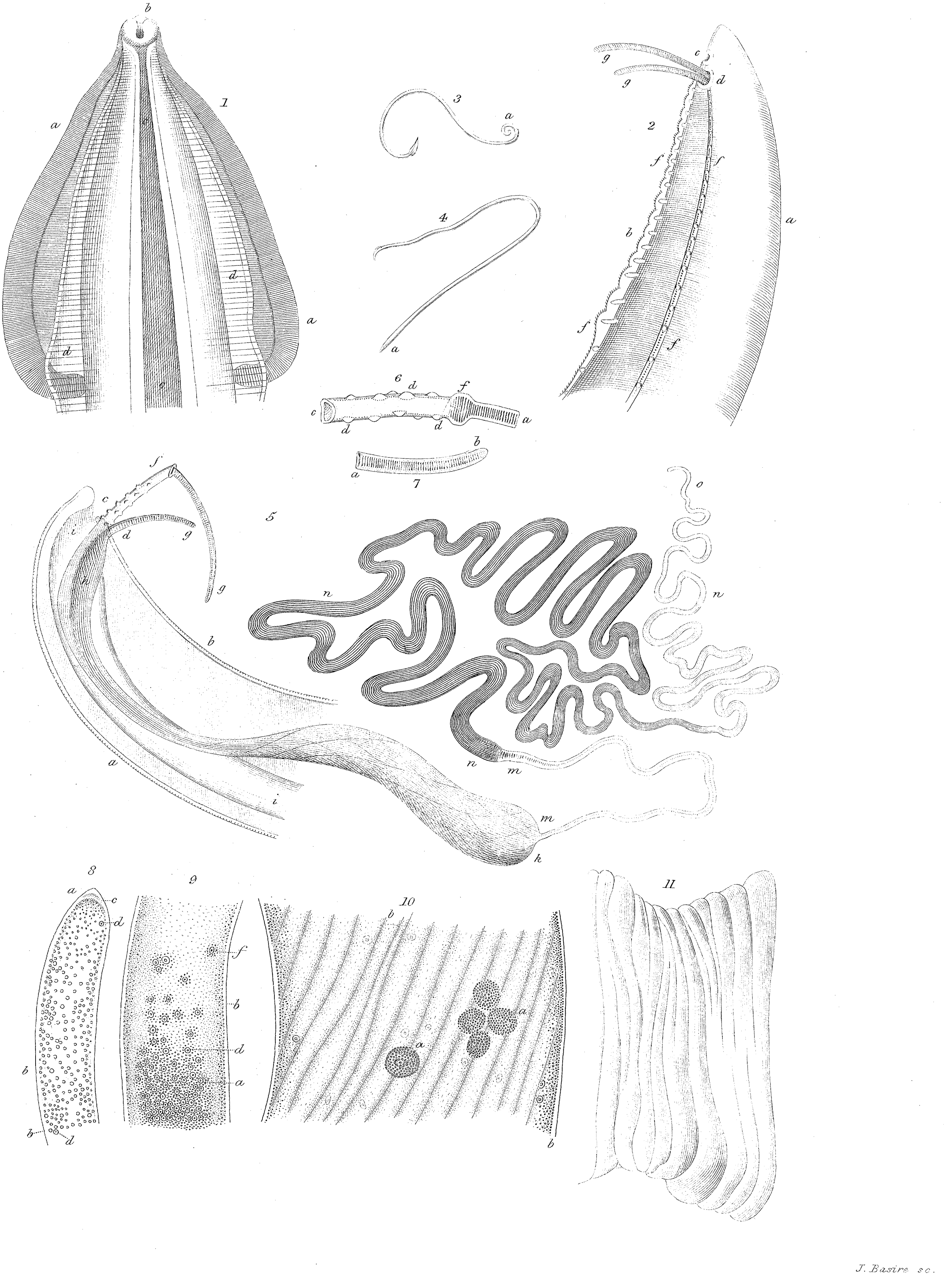


Fig. 5. — Art. 109.



G. G. Stokes del.

J. Basire sc.



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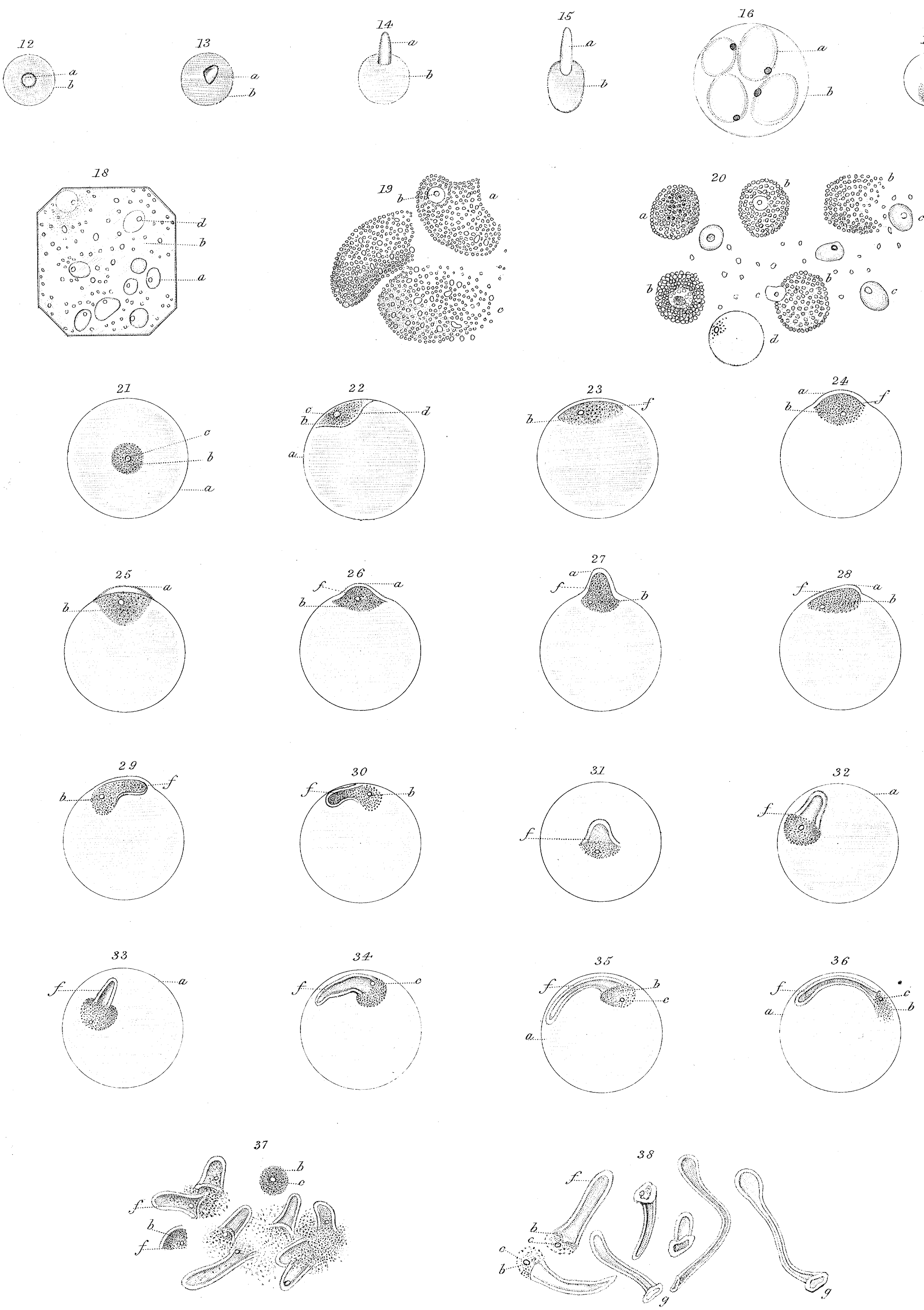

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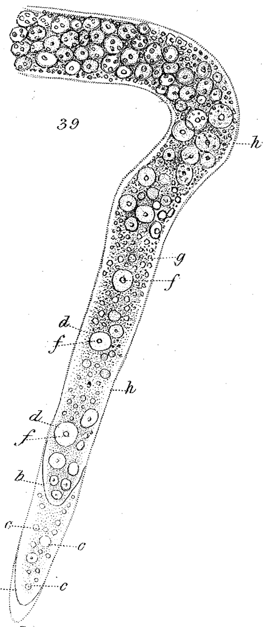
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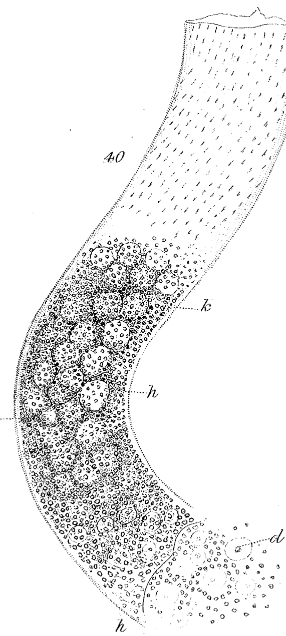
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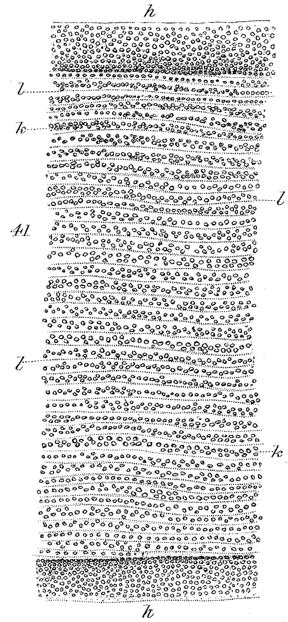
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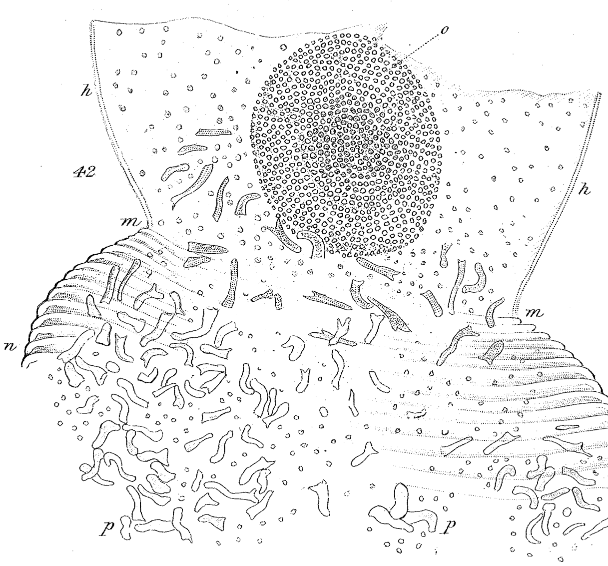
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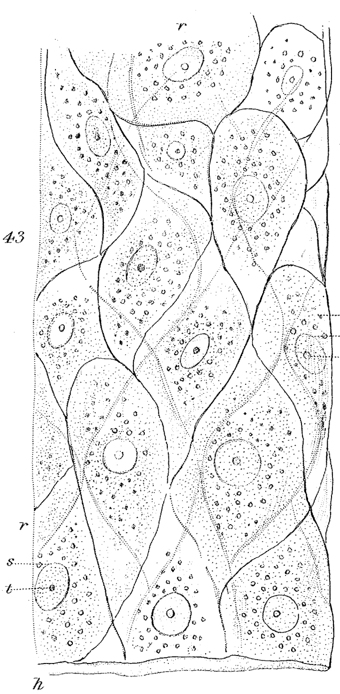
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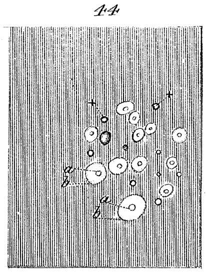

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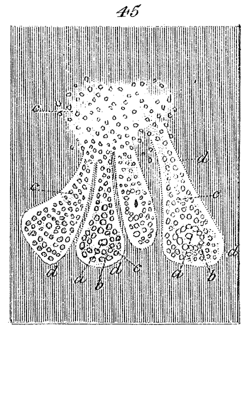

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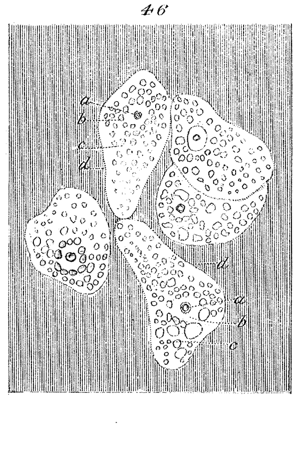

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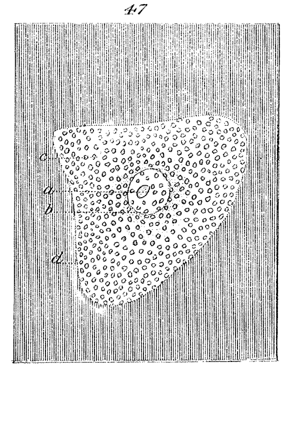

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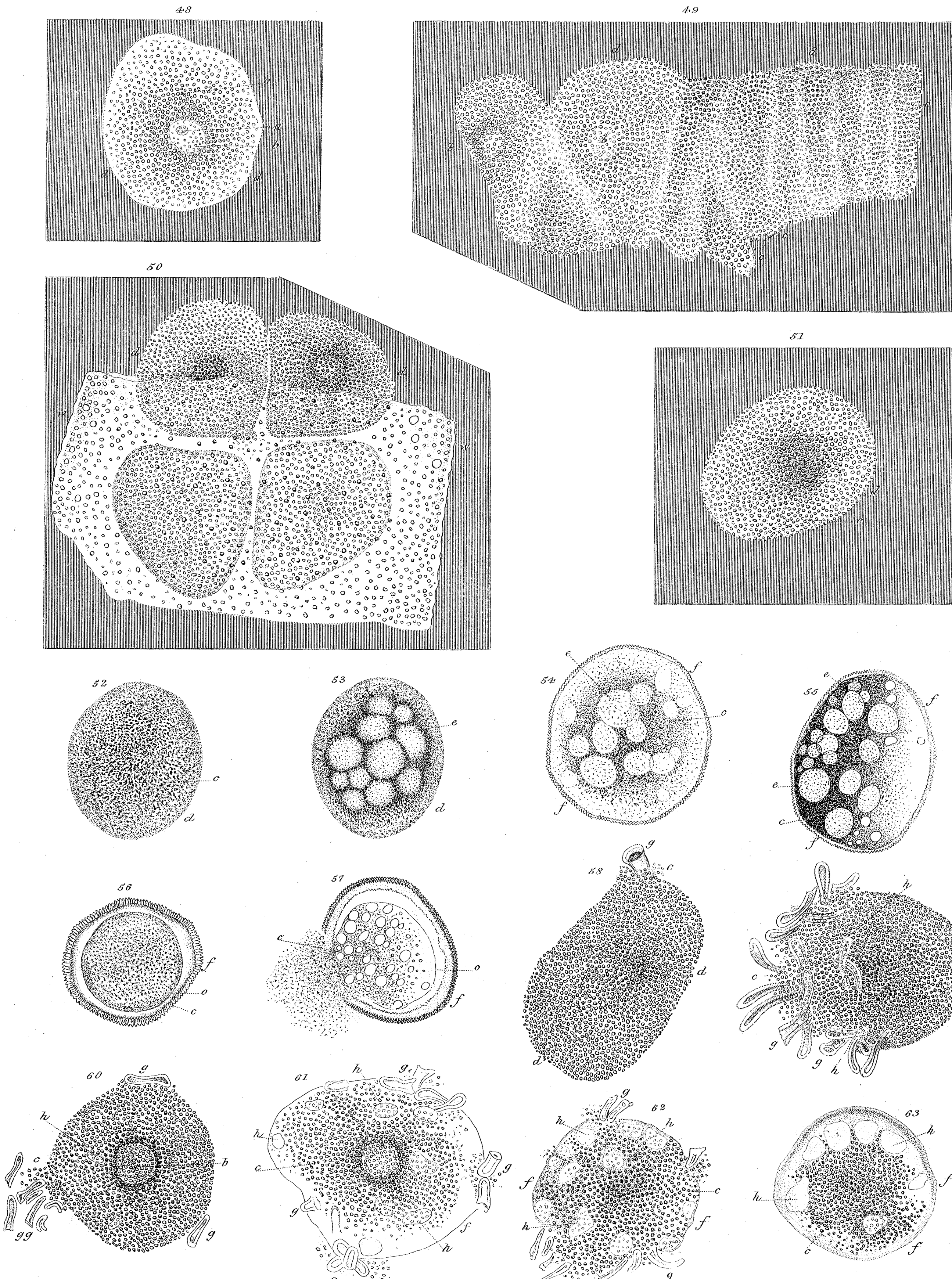

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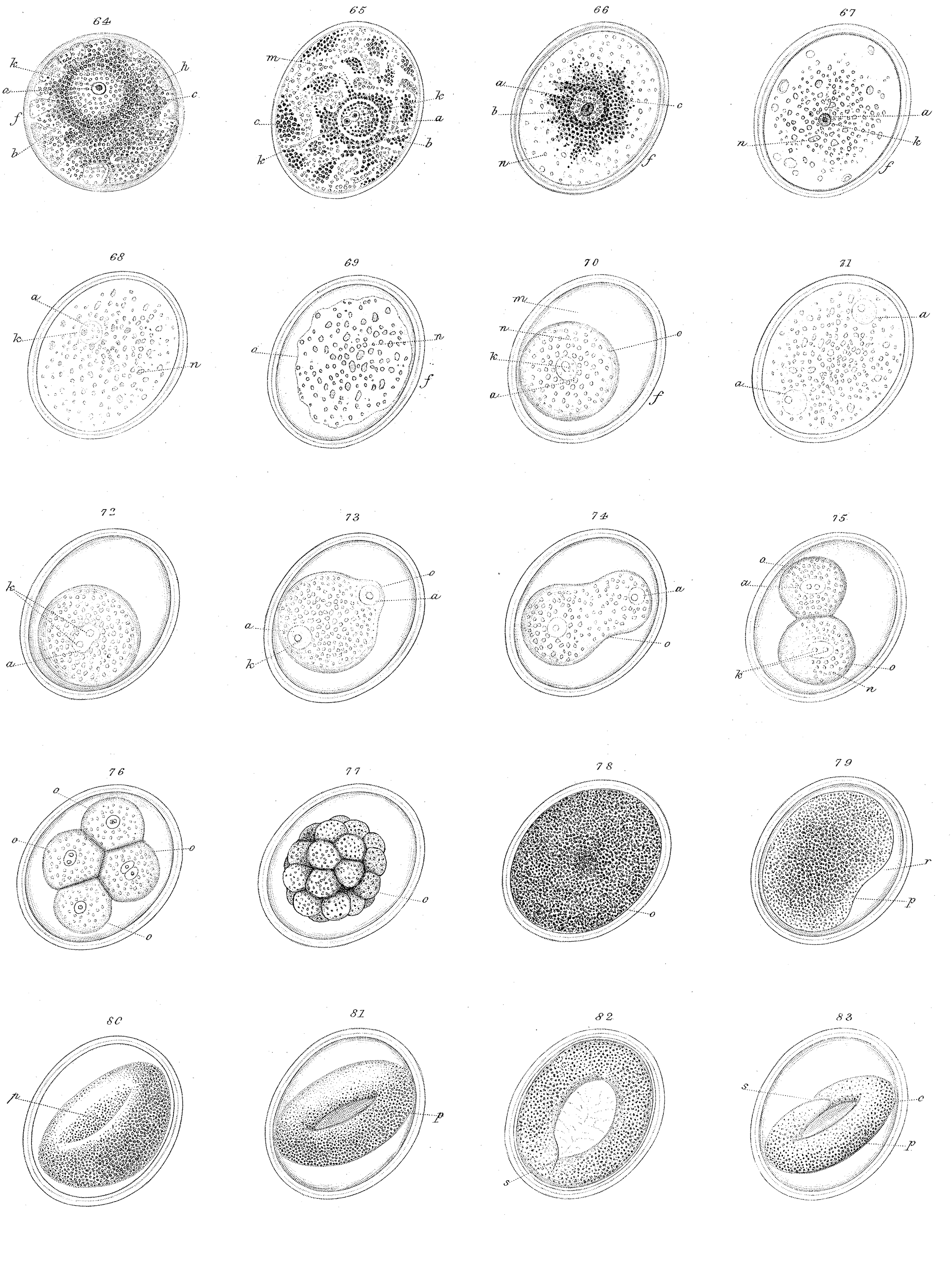

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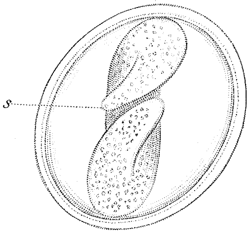

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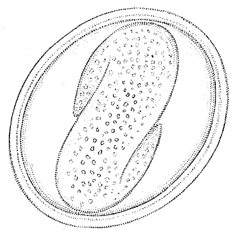

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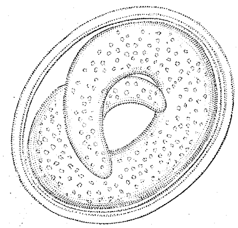

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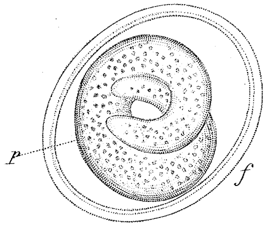

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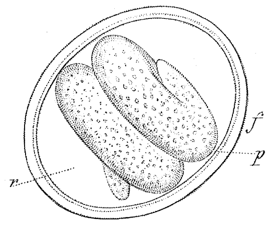

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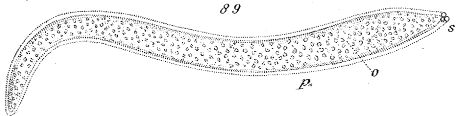

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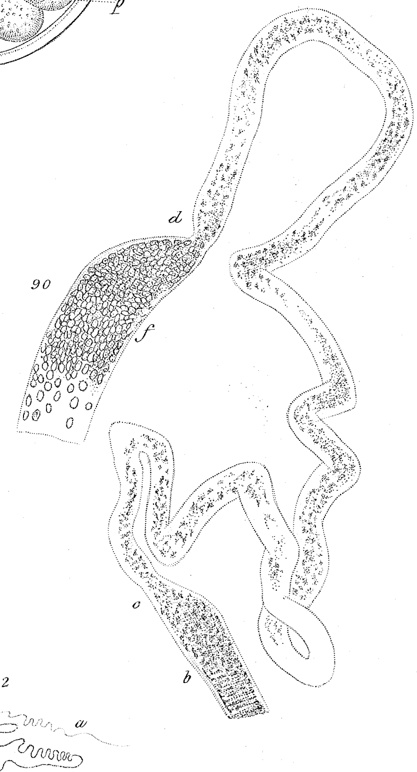

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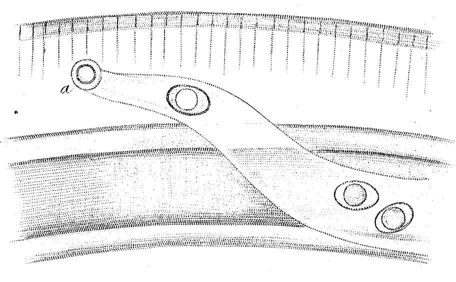

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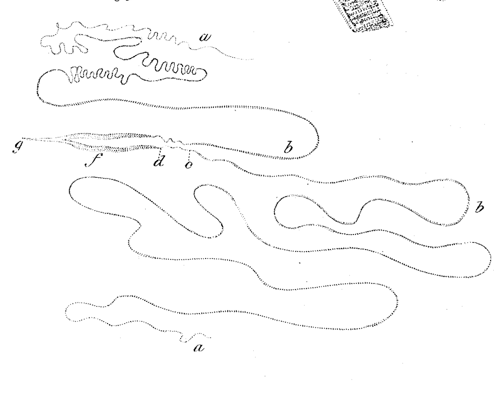

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